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STABILITY OF AËROPLANES.*

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THE subject of "Stability of Aëroplanes" is too broad to permit of a discussion of all of its phases in one evening. I shall, therefore, confine myself more particularly to a few phases of the fore-and-aft or longitudinal equilibrium. Although in learning to fly the beginner finds most difficulty in mastering the lateral control, it is his lack of knowledge of certain features of the fore-and-aft equilibrium that leads to most of the serious accidents. These accidents are the more difficult to avoid because they are due to subtle causes which the flyer does not at the time perceive.

A flying machine must be balanced in three directions: about an axis fore and aft in its line of motion, about an axis extending in a lateral direction from tip to tip of the wings, and about a vertical axis. The balance about the lateral axis is referred to as fore-and-aft or longitudinal equilibrium; that about the fore-and-aft axis as lateral equilibrium, and that about the vertical axis is generally referred to as steering, although its most important function is that of lateral equilibrium.

* Presented at the stated meeting of the Institute held Wednesday, May 20, 1914, when Dr. Wright received the Institute's Elliott Cresson Medal in recognition of the epoch-making work accomplished by him in establishing on a practical basis the science and art of aviation.

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If the centre of support of an aëroplane surface would remain fixed at one point, as is practically the case in marine vessels and in balloons and air-ships, equilibrium would be a simple matter. But the location of the centre of pressure on an aëroplane surface changes with every change in the angle at which the air strikes the surface. At an angle of 90 degrees it is located approximately at the centre of the surface. As the angle becomes less, the centre of pressure moves forward. On plane surfaces it continues to move forward as the angle decreases until it finally reaches the front edge. But on cambered surfaces the movement is not continuous. After a certain critical angle of incidence is reached, which angle depends upon the particular form of the surface, the centre of pressure moves backward with further decrease in angle until it arrives very close to the rear edge. At angles ordinarily used in flying, angles of 3° to 12°, the travel of the centre of pressure is in this retrograde movement and is located, according to the angle of incidence, at points between 30 per cent. and 50 per cent. back of the front edge of the surface. The location of the centre of pressure on any given surface is definitely fixed by the angle of incidence at which the surface is exposed to the air.

The placing of the centre of gravity of the machine below its centre of support appears, at first glance, to be a solution of the problem of equilibrium. This is the method used in maintaining equilibrium in marine vessels and in balloons and air-ships, but in flying machines it has the opposite of the desired effect. If a flying machine consisting of a supporting surface, without elevator or other means of balancing, were descending vertically as a parachute, the centre of gravity vertically beneath the centre of support would maintain its equilibrium. But as soon as the machine begins to move forward the centre of pressure, instead of remaining at the centre of the surfaces, as was the case when descending vertically, moves toward that edge of the surface which is in advance. The centre of gravity being located at the centre of the surface and the centre of pressure in advance of the centre of the surface, a turning moment is created which tends to lift the front of the machine, thus exposing the surfaces at a larger angle of incidence and at the same time to a greater resistance to forward movement. The momentum of the machine, acting through its centre of gravity below

the centre of forward resistance, combines with the forward centre of pressure in causing the surface to be rotated about its lateral axis. The machine will take an upward course until it finally comes to a standstill. The rear edge of the surface will now be below that of the front edge and the machine will begin to slide backward. The centre of pressure immediately reverses and travels towards the rear edge of the surface, which now in the backward movement has become the front edge. The centre of gravity again being back of the centre of pressure, the advancing edge of the surface will be lifted as before, and the pendulum effect of the low weight will be repeated. A flying machine with a low centre of gravity, without rudders or other means to maintain its equilibrium, will oscillate back and forth in this manner until it finally falls to the ground.

It will have been observed from the foregoing that the equilibrium in the horizontal plane was disturbed by two turning moments acting about the lateral horizontal axis of the machine; one produced by the force of gravity and the lift of the surface acting in different vertical lines, and the other by the centre of momentum and the centre of resistance acting in different horizontal lines.

It is evident that a low centre of gravity is a disturbing instead of a correcting agent. The ideal form of flying machine would be one in which the centre of gravity lies in the line of the centre of resistance to forward movement and in the line of thrust. In practice this is not always feasible. Flying machines must be built to land safely as well as to fly. A high centre of gravity tends to cause a machine to roll over in landing. A compromise is therefore adopted. The centre of gravity is kept high enough to be but a slight disturbing factor in flight and at the same time not so high as to interfere in making safe landings.

The three forces acting on an aëroplane in the direction of its line of motion are the thrust of the propellers, the momentum or inertia of its weight, and the resistance of the machine to forward travel. If travelling in any other than a horizontal course, a component of gravity in the line of motion will have to be reckoned with. When these forces are exerted in the same line, with the centres of thrust and momentum acting in the opposite direction to that of the centre of resistance, a variation in the quantity of any one, or of all, of these forces will not in

itself have a disturbing effect on the equilibrium about the lateral horizontal axis. But these forces in the ordinary flying machine do not act in the same line. Usually the centre of thrust is high in order to give proper clearance between the propellers and the ground; the centre of gravity is low to enable the machine to land without danger of being overturned; and the centre of resistance is usually between the centres of thrust and gravity. When a flying machine is travelling at uniform speed the propelling forces exactly equal the resisting forces. In case the thrust of the propellers is diminished by throttling the motor, the momentum of the machine acting below the centre of resistance carries the lower part of the machine along faster than the upper part, and the surfaces thus will be turned upward, producing a greater angle and a greater resistance. The same effect is produced if the machine be suddenly struck by a gust of wind of higher velocity from in front. The thrust of its propellers will be temporarily slightly decreased, the resistance due to the greater wind pressure will be increased, and the momentum of the machine (the centre of gravity being low) will in this case also turn the surfaces upward to a larger angle. While these variations in the forces acting in the horizontal line have of themselves a certain amount of disturbing effect, yet it is from the changes of incidence which they introduce that one encounters the greatest difficulty in maintaining equilibrium.

The two principal methods used in preserving fore-and-aft equilibrium have been, first, the shifting of weight so as to keep the centre of gravity in line with the changing centre of lift; and, second, the utilization of auxiliary surfaces, known as elevators, to preserve the position of the centre of pressure in line with a fixed centre of gravity. The first method has been found impracticable on account of the impossibility of shifting large weights quickly enough. The second method is that used in most of the flying machines of to-day.

Flying machines of this latter type should have their auxiliary surfaces located as far as possible from the main bearing planes, because the greater the distance the greater is the leverage and consequently the smaller the amount of surface required. The auxiliary surfaces are usually placed either in front or in the rear of the main supporting surfaces, since they act with greater efficiency in these positions than when placed above or below.

With a view to high efficiency, no part of either the main surfaces or the auxiliary surfaces should be exposed on their upper sides in a way to create downward pressures. One pound of air pressure exerted downward costs as much in propelling power as two pounds of downward pressure produced by actual weight carried. This is due to the fact that the total pressure on an aëroplane is not vertical, but approximately normal to the plane of the surface. This pressure may be resolved into two forces, one acting in a line parallel with the direction of travel, and the other at right angles to the line of travel. One is termed "lift" and the other "drift." With a given aëroplane surface, the drift and lift for any given angle of incidence always bear a definite ratio to one another. This ratio varies from 1 to 12 to 1 to 1, according to the angle of incidence and the shape of the surface. On an average it is about 1 to 6, so that the thrust required of the propeller in the ordinary flying machine is approximately one-sixth of the weight carried. When travelling on a horizontal course the lift is vertical and is exactly equal to the total weight of the machine and load. This load may be real weight, or it may be partly real weight and partly downward pressures exerted on parts of the surfaces. For every pound of weight carried, a thrust of approximately one-sixth pound is required. If, however, instead of real weight a downward air pressure is exerted on some part of the machine, this downward pressure must be overcome by an equal upward pressure on some other part of the machine, to prevent the machine from descending. In this case the horizontal component of the one pound downward pressure will be about one-sixth pound, and the horizontal component of the compensating upward pressure also will be about one-sixth pound, making a total of one-third pound required in thrust from the propellers, as compared with one-sixth pound thrust required by one pound actual weight carried. It is, therefore, evident that the use of downward air pressures in maintaining equilibrium is exceedingly wasteful, and, as far as possible, should be avoided. In other words, when the equilibrium of an aëroplane has been disturbed, instead of using a downward air pressure to depress the elevated side an upward pressure should be utilized to elevate the low side. The cost in power is twice as great in one case as in the other.

The dynamically less efficient system of downward air pres-

sures is used to some extent, however, on account of its adaptability in producing more or less inherently stable aëroplanes. An inherently stable aëroplane may be described as one in which equilibrium is maintained by an arrangement of surfaces, so that when a current of air strikes one part of the machine, creating a pressure that would tend to disturb the equilibrium, the same current striking another part creates a balancing pressure in the opposite direction. This compensating or correcting pressure is secured without the mechanical movement of any part of the machine.

The first to propose the use of this system for the fore-and-aft control of aëroplanes was Penaud, a young French student, who did much experimenting with model aëroplanes in the 70's of the last century. His system is used only to a slight extent in the motor-driven aëroplanes of to-day, on account of its wastefulness of power and on account of its restriction of the manœuvring qualities of the machine.

Penaud's system consists of a main bearing surface and a horizontal auxiliary surface in the rear fixed at a negative angle in relation to the main surface. The centre of gravity is placed in front of the centre of the main surface. This produces a tendency to incline the machine downward in front, and to cause it to descend. In descending the aëroplane gains speed. The fixed surface in the rear, set at a negative angle, receives an increased pressure on its upper side as the speed increases. This downward pressure causes the rear of the machine to be depressed till the machine takes an upward course. The speed is lost in the upward course, the downward pressure on the tail is relieved, and the forward centre of gravity turns the course again downward. While the inherently stable system will control a machine to some extent, it depends so much on variation in course and speed as to render it inadequate to meet fully the demands of a practical flying machine.

In order to secure greater dynamic efficiency and greater manœuvring ability, auxiliary surfaces mechanically operable are used in present flying machines instead of the practically fixed surfaces of the inherently stable type. These machines possess the means of quickly recovering balance without changing the direction of travel and of manœuvring with greater dexterity when required. On the other hand, they depend to a greater

extent upon the skill of the operator in keeping the equilibrium. It may be taken as a rule that the greater the dynamic efficiency of the machine and the greater its possibilities in manœuvring, the greater the knowledge and skill required of the operator.

If the operator of a flying machine were able to "feel" exactly the angle at which his aëroplane meets the air, ninety per cent. at least of all aëroplane accidents would be eliminated. It has been the lack of this ability that has resulted in so large a toll of human lives. Instruments have been produced which indicate closely the angle of incidence at which the machine is flying, but they are not in general use. Nor does the average flyer realize how exceedingly dangerous it is to be ignorant of this angle. Most of the flyers are aware that "stalling" is dangerous, but do not know when they really are "stalling."

A flying machine is in great danger when it is flying at its angle of maximum lift. A change either to a smaller or a larger angle results in a lesser lift. There is this important difference, however, whether the angle be increased or decreased. While a smaller angle gives less lift, it also has less drift resistance, so that the machine is permitted to gain speed. On the other hand, the larger angle gives not only less lift but encounters a greater resistance, which causes the speed of the machine to be rapidly checked, so that there is a double loss of lift—that due to angle and that due to a lesser speed.

The maximum lift is obtained in most flying machines at some angle between 15° and 20°. If the machine be gliding from a height with the power of the motor throttled or entirely turned off, and the operator attempt to turn it to a level course, the speed of the machine will soon be reduced to the lowest at which it can support its load. If now this level course be held for even only a second or two, the speed and the lift will be so diminished that the machine will begin to fall rapidly.

The centre of pressure on a cambered aëroplane surface at angles greater than 12° to 15° travels backward with increase of angle of incidence, so that when a machine approaches the "stalled" angles the main bearing surfaces are generally carrying practically all of the weight and the elevator practically none at all. Under these conditions the main surfaces fall more rapidly than does the rear elevator. The machine noses downward and plunges at an exceedingly steep angle toward the earth. This

plunge would tend to bring the machine back to normal speed quickly were the machine flying at its usual angle of incidence. But at the large angles of incidence the drift is a large part of the total pressure on the surfaces, so that, although plunging steeply downward, speed is recovered but slowly. The more the operator tries to check the downward plunge by turning the elevator, the greater becomes the angle of incidence, and the greater the forward resistance. At ordinary stalled angles the machine must descend at an angle of about 25° with reference to the horizontal in order to maintain its speed. If the speed be already below that necessary for support, a steeper angle of descent will be required, and considerable time may be consumed before supporting speed can be recovered. During all this time the machine is plunging downward. If the plunge begins at a height of less than two or three hundred feet, the machine is likely to strike the ground before the speed necessary to recover control is acquired.

The danger from "stalling" comes in the operator attempting to check the machine's downward plunge by turning the main bearing surfaces to still larger angles of incidence, instead of pointing the machine downward, at a smaller angle of incidence, so that the speed can be recovered more quickly. It is safe to say that fully 90 per cent. of the fatal accidents in flying are due to this cause. Most of the serious ones occur when, after long glides from considerable heights, with the power of the motor reduced, an attempt is made to bring the machine to a more level course several hundred feet in the air. The machine quickly loses its speed and becomes "stalled." All of us who have seen the novice make a "pancake" landing have seen the beginning of a case of "stalling" which might have been fatal had it taken place at a height of one or two hundred feet.

The greatest danger in flying comes from misjudging the angle of incidence. If a uniform angle of incidence were maintained, there would be no difficulty in fore-and-aft equilibrium. As has already been stated, for any given surface and any given angle of incidence the position of the centre of pressure is fixed. Under these conditions, if the centre of gravity were located to coincide with the centre of pressure and a uniform angle of incidence maintained, the machine would always be in equilibrium.

It is in accordance with this principle that experiments the

past year have brought about a considerable advance in the development of automatic stability. A small horizontal wind vane is so mounted on the machine as to ride edge-wise to the wind when the machine is flying at the desired angle of incidence. In case the machine varies from the desired angle, the air will strike the vane on either its upper or lower side. The slightest movement of the vane in either direction brings into action a powerful mechanism for operating the controlling surfaces.

If the wind strikes the vane on the under side, as would be the case when the machine takes a larger angle of incidence, the elevator is turned to cause the machine to point downward in front till the normal angle is restored. If the air strike the vane from above, a smaller angle of incidence is indicated, and an opposite action on the elevator is produced. In this system no particular angle of the machine with the horizontal is maintained. It is the angle at which the air strikes the aëroplane surface that is important. If the vane is set at an angle of 5° with the main supporting surfaces, and the machine is travelling on a level course, increasing the power of the motor will cause it to begin taking on more speed. But as the lifting effect of an aëroplane surface is the product of two factors—its speed and its angle of incidence—any increase in speed will produce a greater lift and cause the machine to rise. The machine will now be turned upward, with the surfaces meeting the air at an angle of 5°. On the contrary, if the power of the motor be reduced or entirely turned off, the machine will immediately begin to decrease in speed, requiring a larger angle of incidence for support. But as soon as the angle begins to increase the air will strike the regulating vane on the underside and the elevator will be turned, pointing the machine downward till the component of gravity in the direction of travel becomes sufficient to maintain the normal speed. In this case the planes will be inclined downward with reference to the horizontal. It is evident that a machine controlled by regulating the angle of the machine with reference to the impinging air is not liable to the dangers of "stalling" already described.

Several other methods of maintaining fore-and-aft equilibrium automatically have been proposed. One utilizes the force of gravity acting on a pendulum or a tube of mercury; the other, the gyroscopic force of a rapidly revolving wheel. In both

of these systems the angle of the machine is regulated with reference to the horizontal, or some other determined plane, instead of with the angle of the impinging air.

In the case just referred to, in which the power of the motor was suddenly turned off while travelling on a level course, with these systems, the planes would be maintained at their original angle with the horizontal without any regard to the angle of incidence. The machine would continue forward till, through the loss of momentum, its speed would become so reduced and its angle of incidence so great that it would be exposed to the dangers of diving.

The pendulum and mercury tube have other serious faults which render them useless for regulating fore-and-aft equilibrium. If the machine suddenly meet with a greater resistance to forward travel, either as a result of change in direction or of meeting a stronger gust of wind from in front, and its speed be ever so slightly checked, the pendulum will swing forward and instead of turning the machine downward, so as to maintain the normal speed, will cause the machine to be inclined upward in front and thus further increase its forward resistance.

The pendulum has proved itself an exceedingly useful device, however, in regulating the lateral stability of aëroplanes. In this case the effects of momentum and centrifugal force act on the pendulum in the proper direction to produce desired results.

I believe the day is near at hand when the flyer will be almost entirely relieved of the work of maintaining the equilibrium of his machine, and that his attention will be required only to keeping it on its proper course and in bringing it safely in contact with the ground when landing.

Wild Silk from Mexico. ANON. (*Bull. Imp. Inst.*, xii, 45.)—Wild silk is obtainable in large quantities in the States of Vera Cruz and Oaxaca, where the Indians use it for rope-making. The sample examined consisted of a flat, loosely-spun, web-like nest, of 12 inches by 18 inches. The web amounting to 24 per cent. of the whole sample, when separated as far as possible from extraneous matter and degummed by boiling soap solution, yielded a gray to grayish-brown silk of good lustre and strength. It is unlikely that the material could be used commercially, owing to the low yield of degummed silk (about 10 to 15 per cent.) and the difficulties of cleaning and carding.

THE SCREW PROPELLER: WITH SPECIAL REFERENCE TO AËROPLANE PROPULSION.*

BY

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(1) INTRODUCTORY.

THE fundamental problem of propulsion is the development of a propulsive force (thrust or pull). This may be viewed in two ways, according as we focus our attention on the medium acted upon (air or water) or on the agent (blade, oar, or float).

Fixing our attention on the medium, we remember that, according to Newton's laws of motion, force is required to accelerate the motion of matter, and to every action there is an equal and opposite reaction. To develop a propulsive thrust it will therefore be sufficient to lay hold of a certain amount of matter and give to it an accelerated motion directed aft, or with a component so directed. This will require the exhibition of a force directed in the line of the acceleration. The resultant reaction, equal and opposite in direction, will be a force acting forward or with a forward component, and hence available as a propulsive thrust.

Thus a Gatling gun firing bullets over the stern of a boat, a boy throwing stones, or a pump throwing water are all ways of producing a propulsive thrust, though differing from those commonly employed.

Again fixing our attention on the agent, we assume a body B of some appropriate form (a propeller blade, an oar, or a float) to move relative to the boat or aëroplane through a mobile but resisting medium, such as water or air. We know by the laws of mechanics and still better by common experience that such motion will meet with a resistance manifested as a force acting from the medium to the body and causing a redistribution of the fluid pressure over the surface. This redistribution of surface pressure, constituting as it does a system of elementary forces,

* The substance of two lectures delivered before the students at the U. S. Army Aviation School, San Diego, California, and communicated by Lieut.-Col. Samuel Reber.

will have a single definite resultant R, and this resultant will have a component Q along the line of relative motion, constituting a resistance to such motion and calling for the expenditure of work in order to sustain it.

The total resultant R as noted represents the distributed system of forces acting on the body B. But the body B is in effect a part of the boat. Hence the boat will be acted on by way of the same force R acting along the connection between B and the boat and constituting an external push to which the boat will respond in such manner as may be determined by other conditions. Thus there may be a number of such forces R, as from a number of propeller blades or a number of paddle-wheel floats, and these will have some one final resultant, and this will constitute a propulsive thrust or pull in answer to which the boat will move along the line of such force, ultimately at a speed which will develop a resistance exactly equal and opposite to the propulsive force.

Thus, in brief, the propulsive blade or body is so moved through a resisting medium (such as air or water), and under such geometrical conditions as to form and direction of motion, that the resistance opposed to the motion will give a reaction having a component directed forward, and hence available as a propulsive thrust or pull.

In dealing with practical problems it is necessary to be able to connect up the dimensions and conditions of operation of the propeller with the propulsive force produced. With the first method of consideration this would require, corresponding to any stated size and form of blade and conditions of operation, a knowledge of just how much water or air the propeller lays hold of, and what acceleration is produced in its motion. With the second method of consideration it would require, corresponding to any stated size and form of blade and conditions of operation, a complete and detailed knowledge of the amount and distribution of pressure over the surface of the blade.

Actually, neither of these results can be determined by purely theoretical analysis. This simply means that our knowledge of the laws of hydro or aërodynamics is not sufficient to deduce from the form of the agent (blade or vane) and the conditions of motion either the resulting reaction on the agent or the detailed result on the water or air. We may, however, develop

important relations between these various quantities, thereby laying a foundation for the application of experimental research to the solution of practical problems.

(2) PROPELLER ACTION FROM CONSIDERATION OF RESULTS ON MEDIUM.

Thus for the first method of consideration:

Let v = velocity of craft forward in f.s.
u = final velocity of air aft in f.s. = total change in velocity of air.
w = final velocity of air transversely in f.s.
mu = velocity of flow of air aft to meet propeller.
A = disc area in square feet or area of column of air acted on.
σ = density in pounds per cubic foot.
T = thrust developed in pounds.
e = efficiency.

The total velocity of flow of air to the propeller is $v + mu$, and the total mass of air acted on will therefore equal $(v + mu)\, A\sigma$.

Then by the principles of mechanics we have as follows:

$$T = \frac{(v + mu)A\sigma u}{g} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

We now recognize four components of the total work as follows:

(1) The useful work Tv.

(2) The work carried away by the residual sternward velocity of the water u.

(3) The work carried away by the residual transverse or rotational velocity of the water w.

(4) The work carried away by and absorbed in turbulence.

These take values as follows:

$$\text{Useful work} = Tv = \frac{(v + mu)A\sigma uv}{g} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Work involved in residual velocity of air u is

$$\frac{(v + mu)A\sigma u^2}{2g} = \frac{Tu}{2}$$

Work involved in residual velocity of air w is

$$\frac{(v + mu)A\sigma w^2}{2g} = \frac{Tw^2}{2u}$$

For the present purpose we may assume the work absorbed in turbulence plus the work involved in the rotational velocity w to be related to the energy relative to the residual velocity u by a factor f.

Then the total lost work will be

$$\frac{(1+f)(v+mu)A\sigma u^2}{2g} = \frac{T(1+f)u}{2}$$

Hence efficiency

$$e = \frac{Tv}{Tv + T\frac{(1+f)u}{2}} = \frac{v}{v + \frac{(1+f)u}{2}} \quad \ldots\ldots\ldots\ldots (3)$$

or efficiency

$$e = \frac{1}{1 + \left(\frac{(1+f)}{2}\right)\left(\frac{u}{v}\right)} \quad \ldots\ldots\ldots\ldots (4)$$

For various values of f and of $\frac{u}{v}$ we have efficiencies as follows:

$\frac{u}{v}$	Values of f							
	.5	1.0	1.5	2.0	2.5	3.5	3.5	4.0
.20	.870	.833	.800	.769	.741	.714	.690	.667
.30	.816	.769	.727	.690	.656	.625	.597	.571
.40	.769	.714	.667	.625	.588	.556	.526	.500
.50	.727	.667	.615	.571	.533	.500	.471	.444
.60	.690	.625	.571	.526	.488	.455	.426	.400
.70	.656	.598	.533	.488	.449	.417	.388	.364
.80	.625	.556	.500	.455	.417	.384	.357	.333
.90	.597	.526	.471	.426	.388	.357	.331	.308
1.00	.571	.500	.444	.400	.364	.333	.308	.286

Table Giving Values of Efficiency.

(3) RELATION OF SPEED, POWER, THRUST.

It is often necessary to use the relations between speed, power, and thrust or pull on the propeller shaft. These may be developed as follows:

Tv = thrust work in f.p.s.
$Tv \div 550$ = thrust horsepower = W
Whence $T = \frac{550\ W}{v}$
Again let s = speed in m.h.
Then 1 m.h. = 5280 ÷ 60 f.m. = 88 f.m. = 1.47 f.s.
Then 88 s = speed in f. m.
and $T = \frac{33000\ W}{88\ s} = \frac{375\ W}{s}$

For $W = 1$ we have table as follows, giving thrust in pounds per *thrust* horsepower at varying speeds in miles per hour:

s	T	s	T
20	18.75	65	5.77
25	15.00	70	5.36
30	12.50	75	5.00
35	10.71	80	4.69
40	9.38	85	4.41
45	8.33	90	4.16
50	7.00	95	3.95
55	6.82	100	3.75
60	6.25	105	3.57

With chain transmission between engine and propellers, and including the losses in transmission, the overall efficiency between the engine and the useful work of propulsion will not usually exceed 50 to 60 per cent. With direct connection as in the typical monoplane the overall efficiency may range some 10 per cent. higher. Hence the thrust per engine horsepower may be expected to range from .5 to .7 these values.

Illustrative Problem:

i.h.p. = 80
th.h.p. = 45
Speed = 60 m.h.
Then $T = 6.25 \times 45 = 281.25$
In equation (1), section (2) let $m = .5$ and $u = .30v$
Then $v = 60 \times 1.47 = 88.2$ f.s., and $u = .30 \times 88.2 = 26.46$ f.s.
Then substituting in (1) we find

$$A = \frac{315 \times 32.16 \times 13.16}{101.43 \times 26.46} = 49.68$$

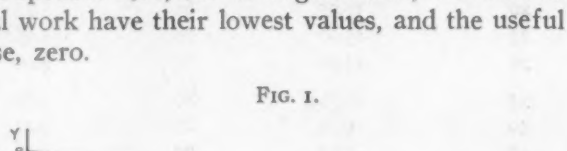
or D 7.95 feet = 8 feet approximately.

Note may here be made of the difference between the thrust when stationary and when moving in free flight, both with a given engine torque.

This is only a special case of the more general problem of the variation of thrust with speed, the engine torque or turning moment remaining constant. See also section (10).

In such case it is found in general, with increasing speed, that the slip and thrust will decrease, while the useful and total work will both increase. *Vice versa,* with decreasing speed the slip and thrust will increase and the useful and total work will both decrease. It results that with a given torque the thrust, when the speed is zero, has its largest value, while the revolutions and total work have their lowest values, and the useful work is, of course, zero.

FIG. 1.



OX, axis of speed; *OY*, axis of resistance and of thrust; *OA*, curve of resistance on speed; *BC*, curve of thrust on speed. Intercepts *KF*, *LE*, etc., show amount of thrust available for acceleration.

These relations should be borne in mind in connection with pulling or thrust tests of propellers with the aëroplane or boat stationary. The thrust or pull developed in such a test is always much in excess of that developed in free flight, while the revolutions and power developed by the engine are less. It results that the engine connected to a propeller does not develop its full power when the boat or aëroplane is stationary. The turning moment may be developed by the engine, but the resistances are such that it is balanced by a combination of high slip and low revolutions, and hence with correspondingly reduced power. Where the craft is free and in motion the slip is reduced, and to balance the constant torque higher revolutions are required, resulting, with

the influence of other factors, in a reduced thrust, increased speed, and in increase in both the useful and the total work.

These relations may be further illustrated by the curves of Fig. 1.

(4) PROPELLER ACTION FROM CONSIDERATION OF FORCES ON AGENT.

We may next consider briefly the derivation of certain relations based on the second viewpoint of propeller action, the consideration of the forces acting on the blade rather than the accelerating effect on the medium.

In the diagram, Fig. 2, let the heavy line denote a small elementary plane which may thus represent an element of an ideal screw propeller.

OK is the direction of movement of the boat or aëroplane relative to the earth or the surrounding still water or air.

OE is the direction of motion of the element relative to the boat.

Suppose the element to rest and move on a smooth, unyielding surface. In other words, suppose that there is no yield to the medium—no movement of the element relative to the medium other than edgewise through it. Then it is clear that while the element moves transversely from *O to E* it must move forward with the boat a distance equal to *EF*.

This would mean operation without propeller "slip."

Actually the distance moved forward will be *EG* some distance less than *EF*.

The distance *EF* for one revolution of the propeller is known as the *pitch*.

Let us use the following notation:

p = pitch = EF for one revolution.
D = diameter.
N = revolutions per minute.
s = slip ratio $FG \div EF$.
$(1 - s)$ = ratio $EG \div EF$.
r = radius of element of area relative to shaft centre.
dA = element of area of surface.
A = total propeller surface.
T = thrust or pull in direction of motion of craft.
R = force opposed to motion of propeller element relative to craft.
P = normal force on element.

Q = tangential force on element.
v = speed of craft forward.
w = speed of element relative to craft.
U = useful work of propulsion = Tv.
e = efficiency.

Let OE now represent specifically the transverse distance moved by the element in one revolution. Then:

$$\begin{aligned} 2\pi r &= OE \\ p &= EF \\ \tan\theta &= p \div 2\pi r \\ p &= 2\pi r \tan\theta \end{aligned} \quad \ldots\ldots(5)$$

Again, if we consider the diagram as representing the distances moved in unit of time, we shall have

$$\begin{aligned} EF &= pN. \\ OE &= 2\pi rN. \\ EG &= v = pN\,(1-s). \end{aligned}$$

whence in general

$$v = PN(1-s) \quad \ldots\ldots(6)$$

$$s = \frac{pN - v}{pN} \quad \ldots\ldots(7)$$

Now, whatever the exact distribution of forces on the surface of the element, they may be represented by a normal force P and a tangential force Q, as indicated in the diagram. Then R, the total resistance to transverse movement, will be the sum of the components of P and Q on a transverse line, represented graphically by AB.

Likewise, T, the total resultant along the direction of motion OK, will be the sum of the two components along this direction, of which that for P is positive or forward and that for Q is negative or astern. The algebraic sum or net forward resultant is represented graphically by DC.

These resultants have values as follows:

$$\left.\begin{aligned} T &= P\cos\theta - Q\sin\theta \\ R &= P\sin\theta + Q\cos\theta \end{aligned}\right\} \quad \ldots\ldots(8)$$

Then Tv = useful work and $2\pi rNR$ = total work.

Also efficiency:

$$e = \frac{Tv}{2\pi rNR} = \frac{(P\cos\theta - Q\sin\theta)v}{2\pi rN(P\sin\theta + Q\cos\theta)} \quad \ldots\ldots(9)$$

It will be apparent that, with other things the same, the efficiency will be greater as Q is less, and less as Q is greater. In the limiting case when $Q = 0$ we shall have

$$e = \frac{Pv \cos\theta}{2\pi rNP \sin\theta} = \frac{v}{2\pi rN \tan\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

If now $N = 1$ we shall have $v = EG = PN\ (1—s)$. But from (5) $2\pi r \tan\theta =$ pitch, whence (10) becomes

$$e = \frac{pN\,(1-s)}{pN} = (1 - s) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

This, therefore, represents the limiting value of the efficiency for a thin plane acting as an element of a screw propeller.

With thickness on the back as in the section of an actual propeller blade, there is experimental evidence that at high values of the slip the actual efficiency may pass this limiting value where s is computed for the pitch on the rear or driving face. The explanation is found in the fact that with thickness the virtual or effective pitch is no longer that of the rear face, but a greater value. This effect depends on the disposition of the stream lines about a body of the form of a propeller blade section. It is very complex in detailed analysis, and can only be here referred to in an incidental way.

In order to make further progress in the development of these equations (8), (9), we must make some assumption regarding the forces P and Q. Only an outline of the procedure to be followed can be here given.

We may assume P and Q in accordance with the following principles and approximate relations:

(1) Hydrodynamic forces, such as those here considered, vary closely with the area and with the square of the relative velocity between blade and medium.

(2) Through the slip and the pitch ratio ($p \div D = \pi \tan\theta$) the relative speed of the element through the medium may be related to the speed PN.

(3) The forces P and Q are related to thrust T through the angle θ, and hence through the pitch ratio.

Hence we may write

$$T \propto dA(pN)^2$$

$$\text{Then } U = Tv = Tpn(1 - s)$$

$$\text{Whence } U \propto dA(pN)^3$$

Now for a propeller as a whole made up of a series of such elements we shall have

$$A \propto D^2$$

Hence we may write finally

$$U \propto D^2(pN)^3$$

We must now inquire as to the content of the sign of variation or relation, ($\propto$). On what characteristics and factors of operation will the relation depend? Obviously on all distinguishing characteristics and factors which are not explicitly represented in the formula. These may readily be seen to comprise the following:

(1) The slip ratio s.
(2) The pitch ratio $P \div D$.
(3) The area ratio = total area of blades $\div$ $(\pi D^2/4)$.
(4) The form of the blade.
(5) The thickness of blade and its disposition.
(6) The character of the surface as to smoothness and continuity of form.

We may therefore, if we desire, write

$$U = BD^2(pN)^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

where B is a general factor representing the combined influence of these six factors or influences. Or, again, we may write the equation

$$U = abcdefD^2(pN)^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where the various factors a, b, c, etc., each represent the individual influence of the various characteristics and conditions (1) . . . (6).

In so far as any of these may be made standard,—that is, in so far as variation in these characteristics may be eliminated,—in corresponding measure may we eliminate or discard the corresponding factors. Thus if we may assume (6) to be practically standard or uniform, and if we can assume (5) standard,—that is, always associated in a definite and regular way with certain of the other characteristics, such as diameter and blade area,—then we could discard e and f and reduce the number of factors to four. If, in addition, we could assume a standard form,—that is, a form always definitely and regularly associated

with diameter and area,—then d could be discarded. If, further, we could assume a standard area ratio,—that is, an area always bearing a fixed relation to D,—then we could discard c and thus retain only a and b, the factors relating to pitch ratio and to slip ratio.

On the other hand, to the extent to which these various characteristics can not be made uniform or standard, to such extent will the performance of the propeller depend on such variable features and to a corresponding extent should a complete propeller formula contain factors intended to represent these various conditions.

Referring in general to the two methods of viewing propeller action, and in particular to the equations which directly result from such methods—(1), (12), (13)—it develops that in neither the one case nor the other do the resulting equations by themselves serve to establish any complete or satisfactory relation between the characteristics of the propeller and the general schedule of requirements to be met.

In particular, from the first method of consideration, the simple theory which can be thereon developed does not serve to determine quantitatively how much water or air a given propeller will lay hold of or how much it will accelerate its motion. It does not serve, therefore, as an adequate basis for the actual design of a propeller suited to a specified program of requirements. Similarly, the second mode of consideration does not serve to determine quantitatively the forces which act on the blade of a given propeller, or their distribution over its surface. Specifically in equations (12) and (13) the theory as developed furnishes no basis for the numerical computation of the general factor B or of any of the various factors a, b, c, etc., which go to make up its complex value.

It results that only through experimental research or the investigation of actual cases can we determine the numerical values of the factors which thus stand between the simple theory and the requirements of actual design.

To this end equations (12) and (13) are much more directly available than those furnished by the first method of consideration. In any case and whatever the viewpoint, the equations must be thrown substantially into the form of (12) or (13) before they can be readily applied to the purposes of design.

(5) APPLICATION TO PROBLEMS OF DESIGN.

The practical question now arises, supposing that we know or have given a value of B in (12) or of a, b, c, etc., individually in (13), to what extent and under what limitations can such values be used for purposes of design? This question is of fundamental importance, and the answer should be clearly and accurately understood and its full significance realized. The answer is found in the following:

(1) For purposes of design it is assumed that the mutual forces acting between a solid body and a fluid medium in relative motion depend upon and are determined by the relative velocity and the various other characteristics and conditions as outlined in (1) to (6) above.

(2) That for a given solid body at varying speeds these forces vary directly as the square of the velocity.

(3) That for geometrically similar bodies but varying in absolute size, moving with geometrically similar relations to the medium and hence with geometrically similar systems of stream-line distribution, the total forces at speeds proportional to the square roots of the linear dimension will be proportional to the cubes of the linear dimensions.

Assumption (3) expresses in effect the application of the law of kinematic similitude or of "comparison" so-called, as applied to hydrodynamic problems of this character.

Without taking space for minor details, it is readily shown that these assumptions are equivalent to the statement that in equations such as (12) and (13) the factor B or the various individual factors a, b, c, etc., are independent of absolute size and of absolute speed and can therefore be applied independent of size or speed and dependent only on the particular proportion or characteristic which they are intended each to represent.

It thus results that if for a given propeller we can establish a series of values for a given set of conditions (1) to (6), we may then use these same factors for any propeller, no matter what the actual size or the actual speed, so long as the same set of characteristics and conditions (1) to (6) is fulfilled.

If, then, by means of experimental propellers a sufficient number of experiments could be carried out to furnish a wide range of these factors corresponding to all combinations of the

various characteristics and conditions, the problem of propeller design would be put on a reasonably definite and secure basis. Actually no such collection of data is now available, and present dependence must be placed on somewhat widely scattered results.

It must not be forgotten, moreover, that the independence of these various factors on absolute size or speed is, after all, only an assumption made for the purpose of convenience. With reference to a more refined analysis, it cannot be doubted that both size and speed will have some influence on their values, and hence it should be remembered that in the application of experimental results, or in transferring the results for a given case to the circumstances of a proposed case, the more remote the two cases in point of size and speed, the less certain will be the results, and the nearer they are in these respects, the more dependable will be the results.

The application of the general equation (12) for purposes of design may be shown by a few simple illustrations.

For a given propeller we have the following dimensions and results:

$D = 7$ feet.
$p = 7.7$ feet.
$N = 700$.
$v = 48$ miles per hour.
i.h.p. $= 45$.

What should be the diameter of a geometrically similar propeller to absorb with the same slip ratio an i.h.p. of 60 with a speed of 51 miles per hour?

Equation (12) is equivalent to the following statement:

Under similar conditions the power absorbed by a propeller is proportional to the square of the diameter and to the cube of the product pN. Hence,

$$\frac{60}{45} = \frac{D_2^2}{49}\left(\frac{p_2 N_2}{p_1 N_1}\right)^3$$

But with equal values of the slip ratio s, the product pN will vary as the speed v. Hence we have

$$\frac{60}{45} = \frac{D_2^2}{49}\left(\frac{51}{48}\right)^3$$

Whence

$D_2 = 7.38$ feet $= 7$ feet 4.5 inches
$p_2 = 1.1 \times 7.38 = 8.12$ feet $= 8$ feet 1.4 inches
$p_2 N_2 = \left(\frac{51}{48}\right) 7.7 \times 700 = 5726$
$N_2 = 5726 \div 8.12 = 705$

Suppose, again, a propeller similar in geometrical form to No. 1, but 20 per cent. smaller in size. At a speed of 60 miles per hour how much power will it absorb under the same circumstances and with the same slip as No. 1?

Since the slip ratio is the same we must have the product pN in the ratio of the speed.

Hence

$$p_2N_2 = p_1N_1 \times \frac{60}{48} = 7.7 \times 700 \times \frac{60}{48} = 6737$$

But

$$p_2 = 7.7 \times .80 = 6.16 \text{ feet.}$$

Therefore

$$N = 6737 \div 6.16 = 1094.$$

$$\text{Then i. h. p.} = 45 \times (.8)^2 \times (1.25)^3 = 45 \times .64 \times 1.95 = 56.2$$

(6) SLIP OF PROPELLER AND STERNWARD ACCELERATION OF MEDIUM.

The term slip is sometimes used loosely with reference either to the medium or the propeller. The slip of the propeller is, however, not the same thing as the sternward acceleration of the medium. Each of these has been suitably defined in the preceding paragraphs. They are entirely different physical quantities. Comparing the slip of the propeller, FG (Fig. 2) with the sternward acceleration u in section (2), and denoting the former per minute by S, it may be shown that in the case of an ideal blade without friction we shall have

$$u = 2S$$

In the actual case with friction, no general relation can be established, but as a broad rule u will be less than the above value for the ideal case.

(7) REACTIONS BETWEEN CRAFT AND PROPELLING AGENT.

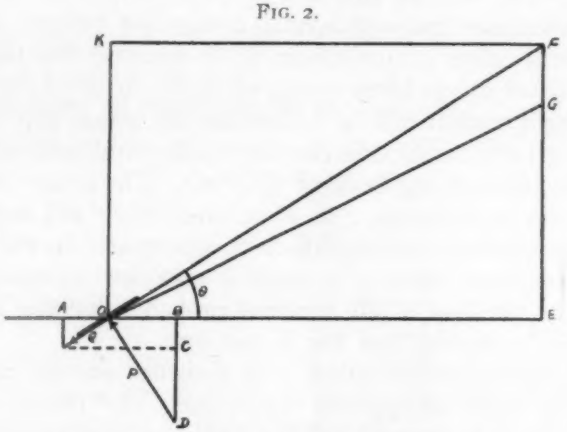
We must next consider briefly the mutual relations between the boat or aëroplane and the propelling agent. These relations may be noted under two heads, as follows:

(1) *Reaction of Propeller on Craft.*—This is in the nature of an augmentation of resistance as compared with the force which would be required to maintain the craft alone, drawn or forced through quiet air at the same speed. In the case of pro-

pellers located in the rear and operating by thrust, this augmentation comes by way of a driving or pumping of the air away from the after parts of the structure, thus diminishing the air pressure on these parts compared with the pressure which would prevail if the craft alone and without propeller were drawn or forced through the air at the same speed. This action is then, in effect, a diminution of the following air pressure on the structure, and a resulting increase in the difference between the resultant pressures acting from forward aft and from aft forward, and a consequent increase in the resistance opposed to propulsion.

In the case of propellers located at the bow (tractors) the augmentation comes by way of a current or blast of air driven

FIG. 2.



Force reactions between element of blade and medium.

aft by the propeller against the forward surfaces of the structure, thus increasing the pressures directed from forward aft, and hence increasing the difference between the resultants in the two directions, and hence the resistance to propulsion.

(2) *The Reaction of the Structure on the Propeller.*—This comes by way of a disturbance of the air in which the propeller operates, thus modifying in effect the slip ratio, and thus one of the fundamental conditions of operation.

With the propeller forward, as in the tractor, this reaction is small, and for practical purposes may probably be considered as negligible. With the propeller astern the action is more pro-

nounced. The motion of the structure through the air tends to develop a following wake of air, closing in about the propeller to a greater or less degree and constituting a sort of following current in which the propeller operates. With water and the usual ship-formed body this action is very pronounced, and must be considered in any careful analysis of the problem of propulsion. In the case of the ordinary biplane structure and a gaseous medium such as air it may be expected that the following current will be less pronounced than with the usual boat-formed body and a liquid medium. Nevertheless, the same principles obtain in the two cases, and the likelihood of some reaction similar to that in the case of water should not be overlooked.

The air thus acted on will be thrown into turbulence, and the practical result will be that the propeller is forced to operate in a turbulent medium with a small component velocity forward. The general effect of turbulence is to decrease the thrust developed, other things being equal, while the effect of the following resultant motion will be to increase the actual slip and thus to give a greater thrust than that due to the conditions of motion relative to the outlying body of quiet air. These two influences are opposite in direction. To what extent they will annul each other is not known with satisfactory exactness. In the case of water propulsion there is a marked resultant increase in the thrust. In the case of air it seems probable that the resultant action will be similar, but less in amount.

These two reactions between the propeller and the craft thus presumably trend in opposite directions. The reaction of the propeller on the structure tends to increase the resistance and thus the actual propeller thrust which must be developed. On the other hand, the reaction of the following current tends to place the propeller in such conditions of operation that the needed thrust is realized with lower revolutions and hence with less power than would be the case in undisturbed air.

In the case of water propulsion these two effects very closely counterbalance so far as the final work of propulsion is concerned. In the case of air propulsion, further experimental data are required before any definite statement can be made regarding this point.

In considering this matter of the reaction between the structure and the propeller, a final point should be noted in connection

with the two values of the slip and the corresponding two values of the efficiency which may present themselves for consideration.

Thus the speed through the air, considered as a surrounding quiet medium, is a matter of direct observation. So also are the revolutions. The pitch of the propeller is known.

The slip $s_1 = (pN - v)/pN$ is a simple matter of observation. It is not, however, the actual slip of the propeller relative to the air in which it works. Suppose that the air about the propeller has an effective following velocity measured by wv where w is some small factor. Then the velocity of the propeller through or relative to this air is $v - wv = (1 - w)v$. The true slip, that relative to the air in which the propeller is actually working, will be therefore measured by

$$s_2 = \frac{pN - (1 - w)v}{pN}$$

From these we readily derive the following:

$$1 - s_1 = \frac{v}{pN}$$

$$1 - s_2 = \frac{(1 - w)v}{pN}$$

$$\frac{1 - s_2}{1 - s_1} = 1 - w$$

The slip s_1 is usually called the apparent slip and s_2 the true slip. Corresponding to these we have two values of the propeller efficiency, one as determined by the apparent slip in conjunction with the other characteristics, and called the apparent efficiency, and one as determined by the true slip with the other characteristics, and called the true efficiency.

(8) SIDE TIPPING MOMENT DUE TO TORQUE.

Since action and reaction are equal, it is clear that the turning moment developed by the engine will tend equally to rotate the shaft relative to the aëroplane and the aëroplane relative to the shaft. The shaft rotates rather than the structure of the aëroplane simply because there is less resistance to such rotation. The moment exists, however, and would produce a slow rotation of the structure in one direction and a rapid rotation of the shaft in the other but for the corrective effect of ailerons or of

a pendulum, disposition of the weights of the structure, or both in combination.

The magnitude of this tipping moment is readily determined from the horsepower and revolutions.

Thus let W = power developed by engine in i. h. p.
Q = torque
N = r.p.m.

Then $W = 2\pi NQ$

or $$Q = \frac{33000\,W}{2\pi N}$$

Thus for illustration, if $W = 90$ and $N = 900$, we have

$$Q = \frac{33000 \times 90}{2\pi \times 900} = 525 \text{ pound feet.}$$

This would be equivalent to two equal forces of about 26 pounds each, acting one up and the other down, with an arm of 20 feet between them.

If the weights of the structure are so disposed as to give a pendulum effect,—that is, a righting moment due to gravity,—then without aileron effect the structure will incline until the righting moment thus developed equals the tipping moment developed by the engine torque. With aileron control the result will be a combination of the two factors, the details of which will depend on the circumstances of the case.

In the case of twin propellers rotating in opposite directions, as in the typical Wright biplane construction, these moments are equal and in opposite directions and thus balance, leaving the propulsive effort without residual turning moment on the craft.

(9) LONGITUDINAL TIPPING MOMENT DUE TO THRUST.

The thrust is applied approximately along the line of the shaft. The centre of resistance of the structure with any particular configuration of planes, ailerons, and rudders may lie above, below, or on this line. If it should lie above the line the combination of the thrust and the resistance will form a couple tending to elevate the head of the structure. If it lies below the line the result will be a couple tending to depress the head, and if on the line there will be no such couple and the angular aspect of the structure will not be affected. It may thus result that a given machine will require a constant corrective use

of the vertical rudder to control this tendency for either the head or the tail to lift. Such a result implies an improper disposition of weights or plane surfaces relative to the location and direction of the shaft. Such a continued or set condition of a vertical rudder, while it may serve to correct the tendency to curving flight, will nevertheless be at the expense of an increased resistance and a corresponding loss in speed for the same engine power.

(10) ACCELERATION OF SPEED FROM REST TO FINAL STEADY CONDITION.

Another topic closely related to the variation of thrust with speed, the engine torque being constant, is the gaining of speed from a condition of rest.

It will be clear for any given value of the engine torque with a given propeller and craft that there will be some speed of advance for which the thrust or pull developed by the propeller will be exactly balanced by the resistance developed by the craft, and hence a condition of steady flight will result. If, however, the speed has some value v less than this final steady condition speed v_1, then the resistance will be correspondingly less while the thrust will in general be actually more. It will result that there will be a part of the thrust not balanced by the resistance and hence available as an accelerating force. In answer to such force the speed will gradually increase, closing down the gap between v and v_1 and thus approaching the final value v_1.

With the increase in speed, however, there will come a corresponding increase in resistance, a resultant decrease in the margin available for acceleration, and a resultant decrease in the rate of closing the gap in speed. Thus at the start from rest the entire thrust is available for acceleration and the acceleration in speed is correspondingly large. This steadily decreases as the speed increases, and there is thus a gradual approach with a slower and slower acceleration to v_1, the final speed for steady flight. It is of interest to note that under ideal conditions,—that is, with absolutely quiet air and uniform engine torque,—the equations for these relations take such form as to show that the time and distance required for the ultimate realization of the final speed v_1 would both be infinite. The physical reason for this is found in the gradually-decreasing value of the acceleration

as the gap to be closed becomes less. The speed v_1 from rest thus represents the summation of a series of terms, infinite in number and indefinitely decreasing in magnitude with increase of time. In the same way the time required to fully realize any increase in speed corresponding to a change in engine torque would theoretically be indefinitely great.

In a similar manner with a given condition of steady flight, if the engine torque is reduced there will be an excess of resistance over thrust which will operate as a retarding force. This will reduce the speed gradually from v toward the smaller steady condition value v_1. In a similar manner, likewise, the retarding force will decrease as the difference between v and v_1 is less, and the gap will therefore be closed by an indefinitely diminishing series of elements. In this case, the same as for gaining speed, ideal conditions give equations indicating an indefinite time and indefinite distance for realizing the ultimate speed corresponding to the reduced torque.

Actually the important question is not the time or distance required to realize the ultimate speed corresponding to a given engine torque, but rather the time or distance required to realize a substantial closure of the gap between the original speed v and the final speed v_1. Thus if the total ideal change is .90 or .99 realized, the result is a substantial fulfilment of the conditions, and the time and distance for such practical fulfilment are always finite quantities, large or small, according to the factors and circumstances of the case.

Actually, moreover, the conditions regarding resistance and engine torque are never perfectly uniform. The resistance is constantly changing, due to varying external conditions and the torque due to varying conditions affecting the motor. The result of these various interacting factors is a continually changing state regarding speed and acceleration in which there is a constant effort on the part of the forces involved to maintain an adjustment with the changing conditions, but in which there is a time lag, so that the adjustment is always lagging behind the changing conditions.

These circumstances furnish an illustration of a problem of pursuit in which the changing speed may be said to be continually in pursuit of the changing conditions, but always lagging behind in the race.

These relations are further illustrated by the diagrams of Fig. 3.

(11) CENTRIFUGAL FORCE ON BLADES.

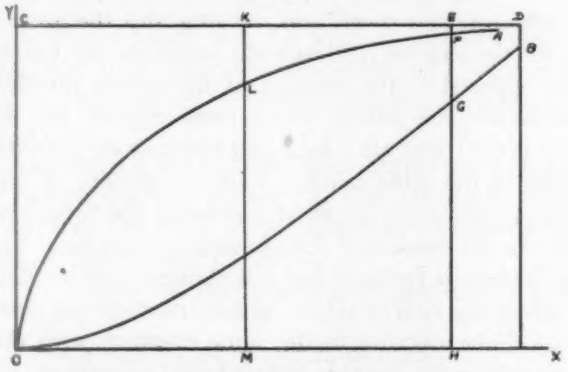
At high rotative speeds the centrifugal force developed may become a matter of importance with reference to the stresses developed at the root of the blade.

Let W = weight of blade.
r = radius of centre of gravity.
ω = angular velocity.
n = revolutions per second.
F = centrifugal force.

Then from mechanics we have

$$F = \frac{Wr\omega^2}{g} = \frac{4\pi^2 n^2 Wr}{g}$$

FIG. 3.



OX, axis of time; OY, axis of speed and of distance; OA, curve of speed on time; OB, curve of distance on time; CD, line of steady speed toward which actual speed approaches as a limit. Intercepts KL, EF, etc., = speed increments yet to be gained at any time OM, OH, etc.

Thus for illustration let r.p.m. = 600, $W = 20$, $r = 1.8$.
Then $n = 10$ and $F = 4440$ pounds.
If r.p.m. = 1200, $n = 20$ and $F = 17{,}760$.

Forces of this magnitude will naturally require special consideration with reference to the strength at the root section of the blade for the usual two-bladed form, or with reference to the blade fastenings for the three-bladed form.

(12) EFFECT OF ALTITUDE ON THE OPERATION OF A PROPELLER.

All formulæ for the resistance to the motion of a solid through a liquid or gas contain the density of the medium as a direct factor. It results that the resistance of the aëroplane to propulsion, the lifting force developed by the action of the air on the planes, the propulsive thrust developed by the propeller, and the resistance to transverse movement in opposition to the torque of the engine will all vary directly with the density of the medium, other conditions remaining the same.

It results further, since the weight of the aëroplane remains unchanged, that the constant lifting force must be developed as a result of either (1) increased speed or (2) variation of angle of incidence of planes, or some combination of both. Remembering, furthermore, that resistances, thrusts, and lifts vary approximately as the square of the speed, it follows that if the engine is giving a constant torque we shall have the following combination of results. As the altitude increases and the density of the air decreases the propeller will speed up until at some combination of increased rotative speed and varying slip the steady turning moment of the engine will remain balanced by the transverse resistance opposed to the passage of the blades through the air. Since, however, the lifting force must remain the same (for horizontal flight) and all forces and resistances involving the air are varying in the same manner with the density, it will further result that at the same angle of incidence the thrust will be the same and the slip ratio will remain nearly constant. Steady conditions will then be realized and maintained with a rotative speed varying inversely nearly as the square root of the density, with a speed of flight varying in the same manner, with the lift and thrust constant, with the torque constant (as assumed), and with a power output varying directly with the speed or nearly in the inverse ratio of the square root of the density.

If the angle of incidence is varied with altitude the result becomes more complex and cannot be determined in general terms. Thus if the angle is increased with altitude the thrust and resistance must be greater for the same lifting force. The slip will therefore increase and the increase in revolutions, speed, and power output will be less than for constant incidence.

It must be further remembered that the engine at high alti-

tudes will not give the same torque without corresponding adjustments governing the power developed. The air and fuel indraft per stroke will decrease with the density, and without compensating adjustment the torque cannot be maintained constant. It may be further noted that with increasing rotative speed a constant torque will require greater energy developed per stroke or per cycle, increasing directly with the speed. Hence constant energy per stroke or per cycle will not maintain a constant torque with increasing altitude, and hence will not maintain a constant lift without adjustment of the angle of incidence.

Thus for illustration at 10,000 feet elevation as compared with sea level, the density ratio without regard to change of temperature is about .68. The square root of this is .825, and the reciprocal of .825 is 1.21. Then for horizontal flight with constant engine torque and angle of incidence the thrust and lift will remain the same, while the rotative speed, speed of flight, and power output will all increase by approximately 21 per cent.

(13) GEOMETRY OF THE SCREW PROPELLER.

Imagine a generating line *AB* with one end rigidly fixed to a sleeve or hollow tube which slides on a straight line guide or axis. Such a system may be moved either in rotation or axially or both (see Fig. 4).

The *diameter* of the surface thus generated is naturally the diameter of the cylinder which will just inclose it.

The *pitch* is the axial distance corresponding to a complete revolution of the generating line.

Four variations in the generating line may be noted, as follows:

(1) Straight and at right angles to axis.
(2) Straight and inclined to axis.
(3) Bent or curved in an axial plane.
(4) Bent or curved in a transverse plane.

In any of these cases if the axial and angular movements are in constant proportion, the surface traced by the generating line is called a true helical surface or a surface of *uniform* pitch. If the axial movement varies in proportion with the angular movement, the surface is said to have an axially variable pitch.

Take the case of a straight line generatrix, and generating a surface of uniform pitch. Suppose the surface inclosed by a

cylinder on the surface of which the end of the generatrix will trace out a helical spiral path, $KLMBN$ of pitch $= PQ$.

Let the surface of the cylinder be developed as in Fig. 5. AB represents the developed circumference, πD; BC represents the pitch p, and, as well known, the spiral path develops into the diagonal AC.

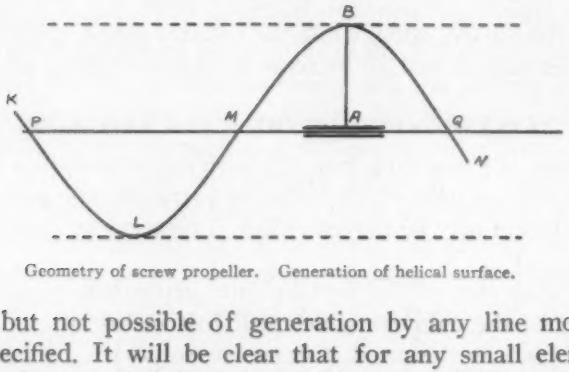
Let θ = angle of inclination of AC to AB.

Then obviously

$$p = \pi D \tan \theta = 2\pi r \tan \theta.$$

Now imagine a helical surface of the most complex character, such, for example, as that given by the rounded back of an ordinary propeller blade, or any other surface smooth and con-

FIG. 4.



Geometry of screw propeller. Generation of helical surface.

tinuous, but not possible of generation by any line moving as above specified. It will be clear that for any small element of such a surface we shall be able to find a true helical surface with the same outside diameter, with a straight generatrix either at right angles or inclined to the axis, and just tangent to the element in question. The pitch of this tangent surface is taken as the measure of the pitch of the element. In this sense any element of surface may be said to have a pitch relative to a specified axis and diameter.

The *face* or *driving face* of a propeller blade is the surface which receives the excess pressure of the air resulting in the propulsive force. It is the after or rear face relative to the craft which it is driving.

The *back* of a blade is the forward surface, opposite the face.

The *leading edge* is the forward or entering edge relative to the movement of the blade through the air.

The *following edge* is the rear or leaving edge relative to the movement of the blade through the air.

The face of the blade is part of a helical surface formed according to some definite law as regards pitch, and usually with straight generatrix at right angles to the axis and with uniform or axially variable pitch.

In the latter case the variation is such as to increase the pitch from the leading to the following edge. This is usually known as an axially expanding pitch.

More broadly it may be seen that any combination of pitch elements may be combined giving variation from centre to tip as well as from leading to following edge and according to any law as may be desired.

The form of the back is determined simply by the need for strength and for thickness to give the requisite material. As will be realized from the broader view of a helical surface, the back may also be considered as such a surface with an extremely variable distribution of pitch. As usually employed, the term pitch refers solely to the driving face. Actually, however, the back may be viewed as composed of a series of elements of surface, each with its pitch as determined by its location and shape. It results that in reality the propeller blade is bounded by two surfaces: a driving face with a uniform or fairly regular distribution of pitch, and a back with an extremely variable distribution of pitch.

The word pitch must therefore be considered as having two meanings or two applications:

(1) The *geometrical pitch*, which refers solely to the driving face and is simply a matter of the form of this surface.

(2) The *dynamic pitch*, which refers to the real dynamic effect of the blade as a whole, with its two bounding faces, each of which has its due influence on the forces acting between the propeller and the medium in which it works.

The former is the usual sense in which the word is employed. It can be determined by simple geometrical measurements. The latter cannot be so determined and can only be inferred as a result of experimental research. In general such investigation shows that the dynamic pitch is greater than the geometrical.

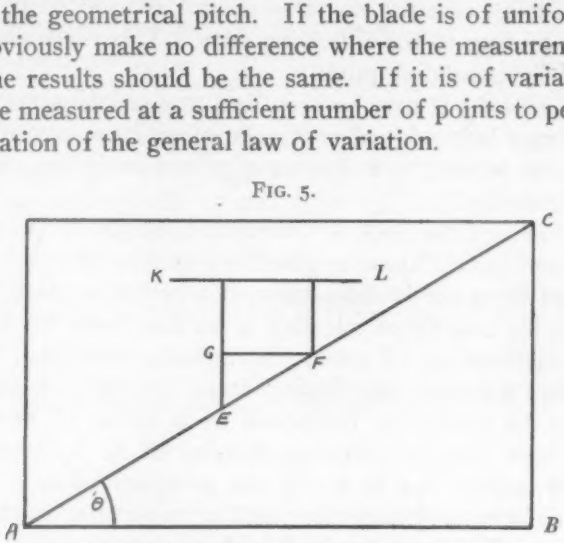
Screw propellers for air craft are usually of wood, with the blades set opposite, permitting of construction by means of con-

tinuous layers, crossing the centres, and thus securing greater strength at the hub than in the case of interrupted blades, as with three- or four-bladed forms.

(14) MEASUREMENT OF PITCH.

A practical problem which may arise relates to the measurement of the geometrical pitch. If the blade is of uniform pitch it will obviously make no difference where the measurements are made: the results should be the same. If it is of variable pitch it must be measured at a sufficient number of points to permit the determination of the general law of variation.

FIG. 5.



Geometry of screw propeller. Developed true helix.

Referring to the equation relating pitch to diameter and angle of inclination we have

$$p = \pi D \tan \theta.$$

At any selected point, then, we have simply to measure the diameter and the tangent of the angle θ.

We may first note that where $\theta = 45°$ $\tan \theta = 1$ and $P = \pi D$.

A quick determination may therefore be made by finding the diameter where $\theta = 45°$ and then taking the pitch $= \pi D$, the circumference on this diameter.

For any selected point we may follow a more general procedure, as follows:

Divide the problem into the four steps:

(1) Select the point and measure the corresponding radius.

(2) Determine a plane of reference perpendicular to the axis of the propeller.

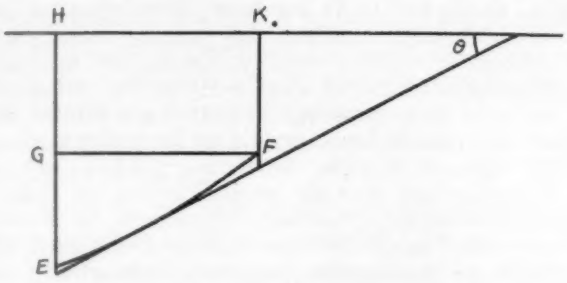
(3) Lay out on the face a line representing the locus of all points distant the given radius from the axis. This is equivalent to laying out on the face a line representing its intersection with the surface of a cylinder on the same axis, and with radius equal to that for the given point on the blade.

(4) Select two points on this line and measure their distance apart on the line and their distances from the reference plane.

Then, referring to Fig. 5, it is plain that the distance between the two points on the line is EF and the difference between the two distances from the plane is GE. Then obviously $\sin\theta = GE/EF$, and

$$\tan\theta = GE / \sqrt{EF^2 - GE^2}$$

FIG. 6.



Developed guide iron for axially variable pitch.

The details of these individual steps will be determined by the resources available, but with a little ingenuity a sufficiently accurate determination can be made with relatively crude appliances.

In any actual case it will be well to repeat the measurement at two or three different values of the radius as a matter of check and to ascertain the possibility of variable pitch at different radial distances from the axis.

This method will give in effect the mean pitch between the two points E and F. If the pitch is variable axially or at different points along EF, and a more accurate determination is desired, then the procedure noted above may be modified as follows:

(1) As before.

(2) As before.

(3) Bend a sheet of tin or thin sheet iron to the curvature of the surface of a cylinder of the given radius.

(4) By cutting and trying fit this sheet so that one edge lies in the plane determined by (1) and the other lies on the surface of the blade, while the sheet itself is in position on the surface of the imaginary cylinder.

This sheet (*EHKF*, Fig. 6) may then be developed out flat again, thus giving the triangle *EFG*. If the pitch is expanding axially the line *EF* will be curved as shown. Then the angle θ at any particular point will be the slope of the tangent to *EF* at that point. In this way the value of the pitch may be found at either leading or following edge or at other intermediate points as desired.

Action of Colloids on Radioactive Products. T. GODLEWSKI. (*Phil. Mag.*, xxvii, 618.)—It has been shown that on passing an electric current through a solution of radium emanation, together with the successive disintegration products, the radioactive substances were deposited almost exclusively at the cathode when the medium was acid or in presence of polyvalent cations and at the anode when the medium was alkaline or in presence of polyvalent anions. This suggests that the radioactive products are present as colloidal hydrosols and that the process is one of electrophoresis rather than electrolysis. Further experiments in which various colloids were added to the solution confirmed this view, and it was found possible to concentrate powerful radioactivity on a few milligrammes of a coagulated hydrosol (*e.g.*, colloidal gold or platinum coagulated by aluminum sulphate). Positive colloids can be precipitated merely by filtering through paper or glass-wool, and in this way radium B and some radium C can be separated from water saturated with radium emanation, the greater part of the β-activity from dilute solutions of uranium nitrate (up to 10 grammes per litre), and some of the disintegration products of thorium and actinium. If a small quantity of aluminum sulphate be added to water containing radium emanation, the negative hydrosols become inversely charged and all the products, radium A, radium B, and radium C, are then retained by a paper filter.

THE COMPUTATION OF COMPOSITE ALTERNATING-CURRENT LINES.*

BY

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IT is proposed to show how conveniently and swiftly the electrical characteristics of a composite alternating-current line can be computed by means of tables and charts [1] of hyperbolic functions. A composite line is defined as one consisting of a plurality of successive sections, each having its own uniform electric constants. It will be evident, from an example of the process, that the tables and charts referred to can be used without any necessary familiarity with the mathematical theory of hyperbolic functions. A moderate acquaintance with the working formulas of ordinary circular trigonometry suffices.

Before analyzing the case to be considered, a few preliminary relations may be outlined.

Every uniform conducting-line circuit, carrying steadily either continuous or alternating currents, overhead or underground, may be regarded as possessing, or subtending, a certain "hyperbolic angle," which is directly proportional to the length of the line, and also depends upon the electrical constants of the line, as well as on the frequency, but is quite independent of the strength or phase of the current carried by the line. The angle subtended by the line is the same whether the line is operated alone, forms part of a transmission system, or is an element in a network of conductors. The angle subtended by a line is, therefore, a fixed property of the line, when the frequency impressed on the line is fixed.

When the impressed frequency is zero,—*i.e.*, when the line is subjected to a continuous electromotive force,—the

* Communicated by the author.

[1] "Tables of Complex Hyperbolic Functions," and "Chart Atlas of Complex Hyperbolic Functions," by A. E. Kennelly, Harvard University Press, 1914.

angle θ subtended by the line is a simple number of what may be called "hyperbolic radians" (abbreviated "hyps."). A continuous-current line subtending 0.5 hyp. or less, would be a short line; but subtending 2.5 hyps. or more would be a long line. When, however, the line is subjected to an alternating electromotive force,—*i.e.*, when the impressed frequency is not zero, the angle of the line is a complex number of the type $\theta = \theta_1 + j\theta_2$ hyps. where $j = \sqrt{-1}$; so that θ comprises a real component θ_1 and an "imaginary" component θ_2. The real component θ_1 of the complex hyperbolic angle θ is a hyperbolic angle, expressible in hyps., or is measured along the arc of a hyperbola. The imaginary component $j\theta_2$ is a circular angle, expressible in ordinary circular radians, or is measured along the arc of a circle.

The complex angle θ, subtended by a uniform line-section, is the geometrical mean of its total conductor impedance Z in ohms, and its total dielectric admittance Y in mhos, or $\theta = \sqrt{ZY}$ hyps. Thus, if a loop line has a total conductor impedance of, say, $Z = 200/\underline{50^\circ}$ ohms, and a total dielectric admittance across the loop of, say, $Y = 0.8 \times 10^{-3}/\underline{70^\circ}$ mho; then

$$\theta = \sqrt{0.16/\underline{120^\circ}} = 0.4/\underline{60^\circ} = 0.2 + j\,0.3466 \text{ hyp.}$$

If a line AB which subtends an angle θ is connected to ground, or zero potential, at one end, say, B, and to an impressed electromotive force at the other end A; then the angle of the grounded end B is zero, the angle of the generator end A is θ; while all intermediate points along the line may be regarded as possessing corresponding intermediate position-angles. Thus, the midpoint along the line has a position-angle $\theta/2$ hyps. If, however, the receiving end B, instead of being connected to zero potential by grounding or shorting, is connected to a terminal load of Z_r ohms impedance, then the angle at B is no longer zero; but θ', as defined by the relation

$$\tanh \theta' = Z_r/Z_o \qquad \text{numeric } \angle \quad (1)$$

where Z_o is the surge-impedance of the line expressed by the formula

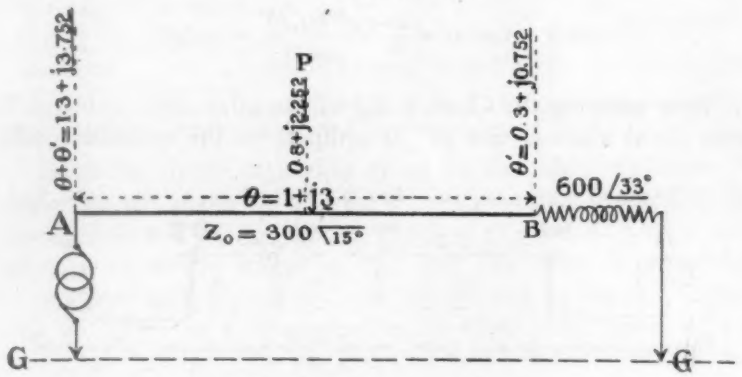
$$Z_o = \sqrt{Z/Y} \qquad \text{ohms } \angle \quad (2)$$

The position-angle of the end A is then increased from θ to $\theta + \theta'$, and all the position-angles of intermediate points along the line become increased by θ'.

Every line, therefore, in addition to subtending an angle θ, depending on the frequency, possesses a terminal angle θ' at its motor end, which terminal angle depends both on the load and on the surge-impedance of the line. The position-angle δ_P at any point P on the line is the sum of θ' and that fraction of θ which its distance from B bears to the distance AB, or total line length.

The current at any point P on the line is then in simple proportion to the cosine of the position-angle, the potential to the sine of the position-angle, and the impedance to the tangent.

FIG. 1.



Angle subtended by a terminal load.

That is, in all cases, the magnitude and phases of currents and voltages are given by:—

$$\frac{I_P}{I_C} = \frac{\cosh \delta_P}{\cosh \delta_C} \quad \text{numeric } \angle \quad (3)$$

$$\frac{E_P}{E_C} = \frac{\sinh \delta_P}{\sinh \delta_C} \quad \text{numeric } \angle \quad (4)$$

$$\frac{Z_P}{Z_C} = \frac{\tanh \delta_P}{\tanh \delta_C} \quad \text{numeric } \angle \quad (5)$$

where C is some point on the line, ordinarily a terminal point A or B, at which the current I_C, the voltage E_C, and the position-angle δ_C are known.

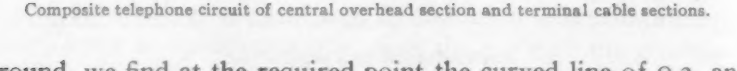
The foregoing relations are illustrated in Fig. 1, which represents a uniform conducting line AB, commonly one side of a metallic circuit pair, considered as operated, in single-wire fashion, to ground or neutral potential GG. At the generator end A

is an impressed alternating electromotive force of single frequency. At the motor end B is a terminal load of $600 \angle 33°$ ohms. At the frequency impressed, the line AB subtends, say, an angle $\theta = 1 + j\,3 \cdot \frac{\pi}{2}$ hyps, or $\theta = 1 + j\,\underline{3}$, where the circular imaginary component is expressed, for convenience of computation, in quadrants instead of radians, and underscored to indicate this fact. The surge-impedance of the line is assumed to be $Z_o = 300 \cdot \angle 15°$ ohms at the impressed frequency. Then the terminal angle at B is given by:

$$\tanh \theta' = \tanh \delta_B = \frac{Z_r}{Z_o} = \frac{600 \angle 33°}{300 \angle 15°} = 2.0 \angle 48°$$

Now entering the Chart XII_A of the atlas above referred to, with 2.0 as abscissa and 48° as ordinate on the rectilinear back-

FIG. 2.



Composite telephone circuit of central overhead section and terminal cable sections.

ground, we find at the required point the curved line of 0.3, and slightly beyond the intersection with the curve of $j\,0.75$. We can readily estimate, therefore, the value of θ' as $0.30 + j\,0.752$, as far as 3 significant digits. From this it follows that $\delta_A = 1.3 + j\,3.752$ and, at the midpoint P of the line, the position-angle $\delta_P = 0.8 + j\,2.252$ hyps.

We may apply the above principles to the case of a three-section composite telephone line like that shown in Fig. 2. Here an overhead line CD, 250 km. (155 miles) long, consisting of a pair of No. 10 A. W. G. (0.259 cm. diameter) at an interaxial distance of 1 foot, with 5 km. (3.1 miles) of standard No. 19 A. W. G. twisted-pair cable at each end. At A is impressed an alternating electromotive force of 2 volts, at $796 \sim$ ($\omega = 5000$ radians per second), the standard telephone frequency; while at F is an impedance of $1500 \angle 70°$ ohms. It is required to find the characteristics of the circuit, and the received current strength

at F. The following table gives the linear constants of the three line sections.

	Section 1 (A–B)	Section 2 (C–D)	Section 3 (E–F)
Section length, km.....	5.0	250.0	5.0
Linear resistance r'' ohms per loop km.....	54.68	6.586	54.68
Linear inductance l'' Henrys per loop km.....	0.6213×10^{-3}	2.284×10^{-3}	0.6213×10^{-3}
Linear capacitance c'' Farads per loop km....	0.3355×10^{-7}	0.4982×10^{-7}	0.3355×10^{-7}
Linear leakance g'' mhos per loop km	3.107×10^{-6}	0	3.107×10^{-6}
Hyperbolic angle at $\omega=5000$, hyps.....	$0.3324+j\,0.2199$	$1.171+j\,2.785$	$0.3324+j\,0.2199$
Surge-impedance per wire, ohms.....	$285.7\angle 42°.843$	$363.7\angle 14°.983$	$285.7\angle 42°.843$

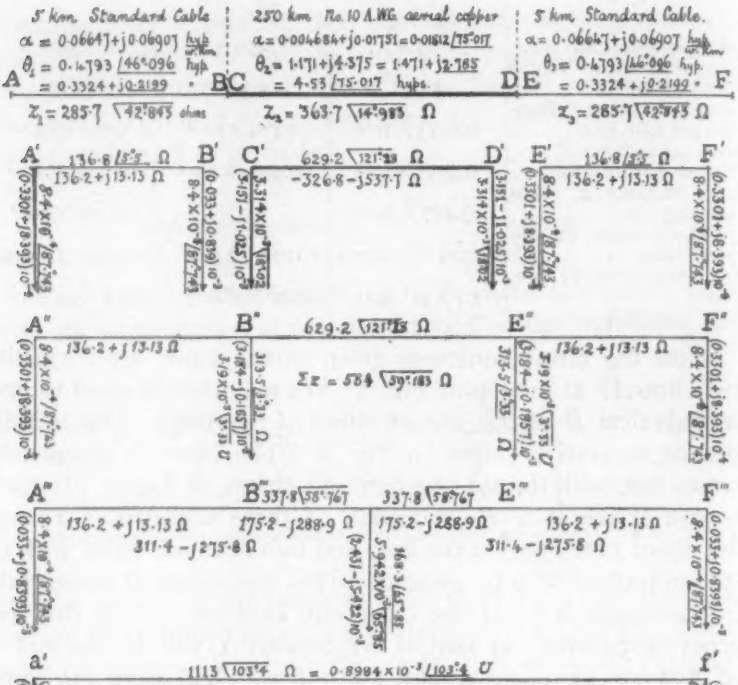
With the linear constants given in the table, we form the single line AF at the top of Fig. 3. We may then proceed to find the equivalent Π of this line, in either of two ways. One is indicated at successive stages in Fig. 3. The other is completely worked out, with the aid of hyperbolic charts, in Fig. 4. In each case we arrive at a Π-connection of three impedances $a\,f\,g\,g$, with about $1110/\underline{103°}$ in the line, and two terminal leaks, each of 2.35 millimho $/\underline{16°.9}$ to ground. This equivalent Π completely represents one wire of the composite loop-line AF at the frequency considered; so that if we connect 1 volt to the end a and $750/\underline{70°}$ ohms to ground from f, we shall have the same entering and leaving currents and potentials at a and f as on the actual line at A and F respectively; although along the actual line the conditions will be very different from those in the middle of the equivalent Π.

In Fig. 3, we commence by establishing the equivalent Π for each section, according to known rules.[2] Thus, each section of cable is represented by an architrave impedance of $136.2+j13.13$ ohms, with a pillar leak at each end of $8.4\times10^{4}/87°.743$ ohm. The three individual section-Πs are now connected in series and are to be reduced to a final single Π by successive steps. At A″ B″ E″ F″ the three Πs are joined together, and adjacent pillar

[2] "The Application of Hyperbolic Functions to Electrical Engineering Problems," by A. E. Kennelly, University of London Press, 1911. (Chapter III.)

leaks are merged. The next step is to remove the central Π, B″ E″, and replace it by its equivalent T, according to the known rules governing such substitutions. This T is indicated at B''' E'''.

FIG. 3.



Successive steps in determining the merger II of the three-section composite line.

This leaves the line A''' F''' with one central and two terminal leaks. By substituting for the central T its equivalent, Π, we obtain the circuit a' f' with terminal leaks only. Merging

terminal leaks, we obtain finally the equivalent Π, $a\ f\ g\ g$, of the three-section composite line. This Π may be called the merger-Π of the line; because it has been derived from the merging of the three individual section-Πs.

The merger-Π can always be computed in the manner above outlined, no matter how many sections appear in the composite line; but the task is very tedious, and liable to arithmetical error. There are first as many individual Πs to be found as there are sections, and then as many but one Π-to-T, or T-to-Π substitutions, each of which is a slowly evolved step.

In Fig. 4 the equivalent Π, $a\ f\ g\ g$, of the composite line is reached by the process indicated in Fig. 1, of forming the position-angle at the receiving end of each section in turn. It will be noticed that a discontinuity exists in the position-angle at each junction. Thus, taking the junction $D\ E$, the position-angle on the E side of this junction is $0.332 + j\underline{0.2199}$ hyp. Applying formula (1), the position-angle on the D line is $0.36 + j\underline{0.065}$ hyp. After finding the position-angle at A, the architrave impedance ρ_{11} is found by the formula in Fig. 4, where one ratio of cosines enters at each junction. The result is seen to be $1119\angle\underline{103.°1}$.ohms This Π, worked out with hyperbolic functions read from the charts, may be called the hyperbolic-Π of the line, to distinguish it from the merger-Π. In this case there is a discrepancy of about 0.5 per cent. in the modulus, or length-factor, and of about 0.3° in the argument or angle-factor, between ρ_{11} in the hyperbolic- and merger-Πs of Figs. 3 and 4. This may be due to small errors in reading off the values of the functions from the hyperbolic charts, which do not pretend to permit of a higher degree of precision than this. If greater numerical precision is required, interpolation can be effected numerically between the values given in hyperbolic tables, but at a considerable sacrifice of time. For most engineering purposes, the functions can be found at once, by inspection from the charts, with a sufficient degree of accuracy. The method of Fig. 4 thus becomes a very swift means of evaluating a composite alternating-current line. The hyperbolic-Π can be worked out, as shown in Fig. 4, in a small fraction of the time needed to work out the merger-Π outlined in Fig. 3.

Figs. 3 and 4 show at a glance that if the line be grounded at B, and 1.0 volt is applied at A, to standard phase, the current flowing to ground at F will be about $0.895\ /\underline{103°}$. milliampère,

which is really a current lagging $360°-103° = 257°$ behind the impressed electromotive force at A. But if we connect the end F to ground through an instrument of $750/70°$ ohms impedance, this instrument is virtually shunted by the pillar leak of $426 \setminus 16°.9$

FIG. 4.

$$\delta_D = \tanh^{-1}\left(\frac{Z_3}{Z_2}\tanh\delta_E\right) = \tanh^{-1}\left(\frac{285{\cdot}7\setminus 42{\cdot}843}{363{\cdot}7\setminus 14{\cdot}983} \times 0{\cdot}4713/41°5'\right) = \tanh^{-1}(0{\cdot}3703/13°{\cdot}64)$$

$$\begin{aligned} \delta_D &= 0{\cdot}36 + j0{\cdot}065 \\ \theta_2 &= 1{\cdot}171 + j2{\cdot}785 \\ \delta_C &= 1{\cdot}531 + j2{\cdot}850 \end{aligned}$$

$$\delta_B = \tanh^{-1}\left(\frac{Z_2}{Z_1}\tanh\delta_C\right) = \tanh^{-1}\left(\frac{363{\cdot}7\setminus 14{\cdot}983}{285{\cdot}7\setminus 42{\cdot}843} \times 1{\cdot}094/2°{\cdot}43\right) = \tanh^{-1}(1{\cdot}393/30°{\cdot}29)$$

$$\begin{aligned} \delta_B &= 0{\cdot}575 + j0{\cdot}685 \\ \theta_1 &= 0{\cdot}332 + j0{\cdot}220 \\ \delta_A &= 0{\cdot}907 + j0{\cdot}905 \end{aligned}$$

$$A_1 = Z_1 \sinh\delta_A \cdot \frac{\cosh\delta_C}{\cosh\delta_B} \cdot \frac{\cosh\delta_E}{\cosh\delta_D}$$

$$= Z_1 \sinh(0{\cdot}907+j0{\cdot}905) \cdot \frac{\cosh(1{\cdot}531+j2{\cdot}850)}{\cosh(0{\cdot}575+j0{\cdot}685)} \cdot \frac{\cosh(0{\cdot}3324+j0{\cdot}220)}{\cosh(0{\cdot}36+j0{\cdot}065)}$$

$$= 285{\cdot}7\setminus 42{\cdot}843 \times 1{\cdot}434/83°9 \times \frac{2{\cdot}263/255°3}{0{\cdot}780/43°9} \times \frac{1{\cdot}00/6°5}{1{\cdot}062/2°1} = 1119\setminus 103°1\ \Omega$$

$$Y_{A_1} = y_1/\tanh\delta_A = 3{\cdot}500\times10^{-3}/42°843/1{\cdot}368/5°6 = 2{\cdot}559\times10^{-3}/37°243 = (2{\cdot}037+j1{\cdot}549)10^{-3}\ \mho$$

$$1/A_1 = 0{\cdot}8937\times10^{-3}/103°1 \qquad Y_{ag} = (-0{\cdot}203+j0{\cdot}870)10^{-3} \cdot$$

$$= (2{\cdot}240+j0{\cdot}679)10^{-3} \cdot$$

$$= 2{\cdot}341\times10^{-3}/16°87 \cdot$$

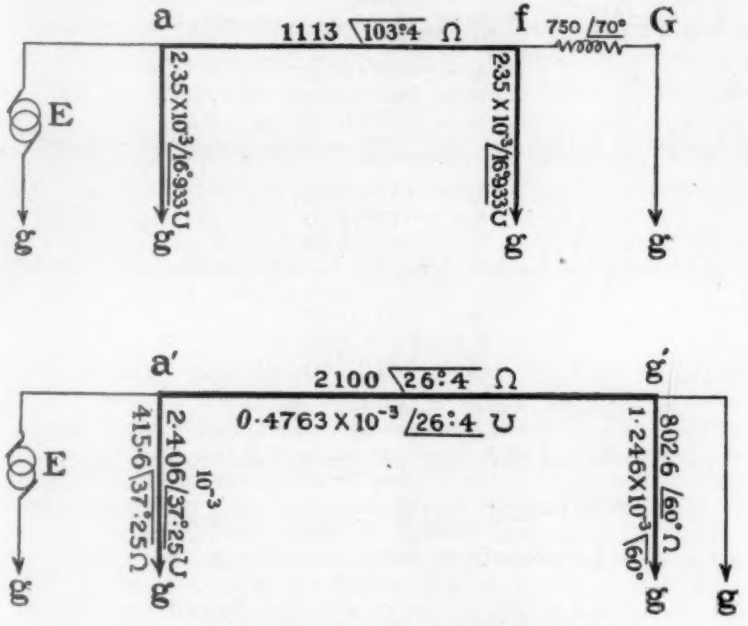
Full computation of hyperbolic Π for the three-section composite line.

ohms; so that the effect of this shunt leak must be taken into account when finding the current through the instrument. In Fig. 5 this is done by substituting a Π for the T—$afGg$; namely, $a'\ g'\ g\ g$. The architrave of this Π, which includes the receiving instru-

ment, is $2100\angle 26°.4$ ohms. If we ground the instrument, the current flowing through it to ground is $0.4763/26°.4$ milliampère.

A short cut to the same result, with the aid of charted hyperbolic functions, is indicated in Fig. 6. Here the position-angle of the section-end F is $\delta_F = -0.132 + j\,0.781$ hyp.; *i.e.*, a negative value of 0.132 hyperbolic radian and 0.781 of a circular quadrant. Three references have to be made to the charts of tangents. The formula for ρ_{11} then requires one reference to a chart of sines,

FIG. 5.



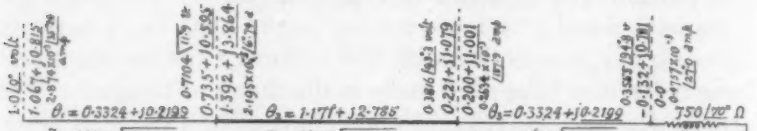
Terminal load and the extension of the merger II to include it.

and seven successive references to charts of cosines. The multiplication calls for the use of the slide rule for the moduli, and simple addition for the arguments. The value of the pillar leak $g'\,g$ does not need to be determined, as the line is worked with G' grounded. The equivalent line impedance, including the receiving instrument, is $2108\angle 26°.5$ ohms, and the received current from $1.0/0°$ volt at A is $0.4744/26°.5$ milliampère in the instrument GG'.

The current and voltage at any point along the line are found in a few moments by formulas (3) or (4), which each call for

two references to the charts. The values of current and voltage at the junctions have thus been supplied in Fig. 6.

FIG. 6.



$$\delta_F = \tanh^{-1}\left(\frac{Z_r}{Z_1}\right) = \tanh^{-1}\left(\frac{750\angle 70^\circ}{285{\cdot}7\angle 42^\circ 843}\right) = \tanh^{-1}(2{\cdot}625\angle 112^\circ 843) = \tanh^{-1}(-1{\cdot}019 + j2{\cdot}420)$$

$$\begin{aligned} \delta_F &= -0{\cdot}132 + j0{\cdot}781 \\ \theta_3 &= \ \ 0{\cdot}332 + j0{\cdot}220 \\ \delta_E &= \ \ 0{\cdot}200 + j1{\cdot}001 \end{aligned}$$

$$\delta_D = \tanh^{-1}\left(\frac{Z_3}{Z_2}\tanh\delta_E\right) = \tanh^{-1}\left\{\frac{285{\cdot}7\angle 42^\circ 843}{363{\cdot}7\angle 14^\circ 983}\tanh(0{\cdot}200 + j1{\cdot}001)\right\} = \tanh^{-1}(3{\cdot}98\angle 28^\circ 31)$$

$$\begin{aligned} \delta_D &= 0{\cdot}221 + j1{\cdot}079 \\ \theta_2 &= 1{\cdot}171 + j2{\cdot}785 \\ \delta_C &= 1{\cdot}392 + j3{\cdot}864 \end{aligned}$$

$$\delta_B = \tanh^{-1}\left(\frac{Z_2}{Z_1}\tanh\delta_C\right) = \tanh^{-1}\left\{\frac{363{\cdot}7\angle 14^\circ 983}{285{\cdot}7\angle 42{\cdot}843}\tanh(1{\cdot}392 + j3{\cdot}864)\right\} = \tanh^{-1}(1{\cdot}137\angle 24^\circ 86)$$

$$\begin{aligned} \delta_B &= 0{\cdot}735 + j0{\cdot}595 \\ \theta_1 &= 0{\cdot}332 + j0{\cdot}220 \\ \delta_A &= 1{\cdot}067 + j0{\cdot}815 \end{aligned}$$

$$\rho_{11} = Z_1 \sinh\delta_A \cdot \frac{\cosh\delta_C}{\cosh\delta_B} \cdot \frac{\cosh\delta_E}{\cosh\delta_D} \cdot \frac{\cosh\delta_G}{\cosh\delta_F}$$

$$= 285{\cdot}7\angle 42^\circ 843 \sinh(1{\cdot}607 + j0{\cdot}815)\ \frac{\cosh(1{\cdot}392 + j3{\cdot}864)}{\cosh(0{\cdot}735 + j0{\cdot}595)} \cdot \frac{\cosh(0{\cdot}200 + j1{\cdot}001)}{\cosh(0{\cdot}221 + j1{\cdot}079)} \cdot \frac{\cosh 0}{\cosh(-0{\cdot}132 + j0{\cdot}781)}$$

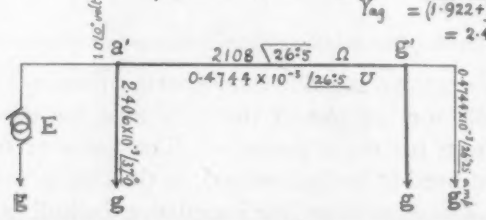
$$= 285{\cdot}7\angle 42^\circ 845\ 1{\cdot}602\angle 76^\circ 9 \cdot \frac{2{\cdot}125\angle 11^\circ}{1{\cdot}002\angle 40^\circ 3} \cdot \frac{0{\cdot}201\angle 90^\circ 6}{0{\cdot}255\angle 120^\circ 16} \cdot \frac{1{\cdot}0\angle 0^\circ}{0{\cdot}363\angle 20^\circ 3} = 2108\angle 26^\circ 5\ \Omega$$

$$Y_{ag} = y_4/\tanh\delta_A = 3{\cdot}500\times10^{-3}/42^\circ 843 / 1{\cdot}218\angle 76^\circ 6 = 2{\cdot}874\times10^{-3}/35^\circ 243 = (2{\cdot}347 + j1{\cdot}658)10^{-3}\ \mho$$

$$1/\rho_{11} = 0{\cdot}4744\times10^{-3}\ /26^\circ 5 = (0{\cdot}425 + j0{\cdot}212)10^{-3}\ \mho$$

$$Y_{ag} = (1{\cdot}922 + j1{\cdot}446)10^{-3}\ \mho$$

$$= 2{\cdot}406\times10^{-3}\ /37^\circ 0$$



Full computation of hyperbolic Π for the three-section composite line including the terminal load.

It is evident that the same process may be extended to any number of sections forming a composite line. Rules have already been worked out for including readily in the hyperbolic-Π of a

composite line the effects of intermediate leaks or series loads along the line.[3] Whereas, however, those rules were developed solely in connection with continuous-current circuits and real hyperbolic functions, the tables and charts of complex functions recently published now admit of the rules being applied with swiftness and ease to intricate alternating-current lines.

In undertaking any new departure in telephone-circuit design, involving new lengths of line, numbers of sections, or types of inserted apparatus, it has been customary to make up in the laboratory an artificial-line system, imitating the new conditions, and to test the same by trial. While in no way detracting from the value of such direct experimental methods, it ought to be possible to carry on an independent check by the computation of the resulting equivalent Π. Without hyperbolic functions, such computations are likely to be hopelessly difficult. With the aid of tables and charts of these functions, the process becomes relatively easy.

[3] "The Equivalent Circuits of Composite Lines in the Steady State," by A. E. Kennelly, *Am. Ac. Arts and Sc.*, October, 1909.

Schilowsky Gyroscopic Monorail Car. ANON. (*Engineer*, cxvii, 106.)—A model of this car is at the Imperial College of Science, South Kensington, London, and is intended for demonstration purposes. A larger example of the system capable of accommodating six passengers is nearly completed. The gyroscopic axis is vertical and two pendulums are provided for automatically controlling the gyroscope. Thus, if the car lurches to the right, the left-hand pendulum pulls a cord and so puts a rack and pinion into mesh. This, in turn, gives such an action on the gyroscope as to call forth for it the desired righting torque and so balance the car.

Scandium. R. J. MEYER, A. WASSJUCHNOW, N. DRAPIER, and E. BODLÄNDER. (*Z. Anorg. Chem.*, lxxxvi, 257.)—Scandium oxide is best prepared from the oxide residues (0.3 per cent. Sc_2O_3) obtained in the manufacture of tungstic acid from wolframite from the Erzgebirge district of Saxony. For its preparation in quantity, free from thorium, the sodium carbonate method, or the ammonium tartrate method is preferred. A number of salts and double salts, complex fluorides, sulphates, and oxalates, are described, and it is pointed out that scandium differs from the other rare earth metals in its more pronounced electro-negative character, its salts showing a marked tendency to hydrolyze and to form stable complex double salts.

Paper and Paper Yarns. C. BEADLE and H. P. STEVENS. (*Chem. News,* cix, 242.)—Note on the dry and wet strengths of paper yarns. The strongest Swedish "kraft" papers used for the manufacture of paper yarns show a tensile breaking length in the machine direction of over 9 km.; papers made from Hedychium for the same purpose show over 10 km. When thoroughly wetted, the strength of the Swedish papers either disappears altogether or is reduced to a negligible quantity, the highest is 0.58 km.; the strength of wet Hedychium papers is still considerable, 1.58 km. The modern process of twisting paper yarns from the finished paper, subsequently moistened, results in a decrease of the dry strength, the yarns from the Swedish papers showing an average breaking length of 6.89 km., and those from Hedychium papers 7.37 km. On the other hand, the strength of thoroughly wet paper yarn is very much greater than the strength of the original paper in the wet state. Yarns from the Swedish papers showed a wet strength of 4.18 km. on the average, and yarns from Hedychium, 4.90 km. This increase of wet strength as between paper and paper yarn is due to the twisting of the strips. Yarn made in the old way, by twisting strips without drying and finishing the paper, gave inferior results, both wet and dry. In the manufacture of yarn, the general rule is to produce a paper of a substance of 40 to 44 grammes per square metre, and to vary the count of the yarn by varying the width of the strips.

Extra High Temperatures. ANON. (*Amer. Mach.*, xl, No. 26, 1106.)—A means of obtaining extra high temperatures from an electric arc is described in the "*Electrician.*" The method consists of combining with an ordinary electric arc a jet of air or oxygen or an oxyacetylene or oxyhydrogen flame. The simplest form of the apparatus has a hollow carbon electrode through which a blast of oxygen or air can be blown. The metal plate to be heated forms the positive pole and the carbon electrode the negative. The arc is struck in the ordinary way and operated by a special mechanism with a hand feed. Several other arrangements may be used, some of which have separate pipes serving to project the oxyacetylene or oxyhydrogen flame on to the electric arc. It is stated that the effect of the oxygen burning inside the arc is to produce a temperature greatly in excess of that of the electric arc alone; also a similar effect is obtained when the oxyacetylene or oxyhydrogen flame burns in the same space as the electric arc.

A PHOTOGRAPHIC NULL METHOD FOR MEASURING ABSORPTION IN THE ULTRA-VIOLET.*

BY

W. R. HAM, Ph.D., R. B. FEHR, M.S., and R. E. BITNER, B.S.

THE primary object of this investigation was to develop a photographic method whereby the absorption of ultra-violet light by various absorbing media could be determined quantitatively.

It is a well-known fact that ultra-violet light (light of wave length less than 390$\mu\mu$) may exert harmful physiological effects on the eye and skin, but just how much of this harm is to be ascribed to general energy radiation, and how much to specific radiation, is a matter that has by no means been settled. It is generally agreed that the extreme ultra-violet rays (those of wave length less than 300$\mu\mu$) cause injury when in sufficient intensity. There are some who claim that the rays between 360 and 300$\mu\mu$ also cause injury. Nutting states in Bureau of Standards Circular No. 28 that the 365th line of the mercury arc contributes 80 per cent. of the "fatigue effect" when this arc is used as a source of light. Whatever may be the extent of the extremely harmful region, there seems to be as yet no clinical evidence to show that the ultra-violet rays which get through glass (glass in general may be said to completely absorb all rays of wave length less than 300$\mu\mu$ from any source) are injurious, unless in greater intensity than is to be found in any commercial light source. There are, however, many industrial processes requiring special protection of the eyes, on account of the excessive amount of ultra-violet radiation. It therefore becomes a matter of importance to know more of the physiological effects of radiation, and to be able to determine how much gets through a given sample of glass or other absorbing medium. Physiological data will no doubt be forthcoming in a few years. The present investigation deals with the other important question: How much ultra-violet light does a given sample of glass transmit?

* Communicated by Dr. Ham from the Engineering Experiment Station, The Pennsylvania State College, July, 1914.

OTHER INVESTIGATIONS.

A great deal of work has been done on ultra-violet light, both in Europe and in America, as shown by the bibliography at the end of this paper. However, very few quantitative investigations have been made. The quantitative researches that seem most important, from the standpoint of the present investigation, are those of Bell and Luckiesh. Dr. Louis Bell, by means of a thermopile and sensitive galvanometer, has obtained valuable data on the ultra-violet component of artificial light. M. Luckiesh has used a photographic method to obtain transmission curves of various kinds of glass; these curves seem to be the only ones on glass. Summarizing, it may be said that such quantitative work as has been done has been confined either to the somewhat troublesome and inconvenient methods of radiometry, or to the simpler and more convenient method of photography with its rather uncertain laws. It seemed desirable, therefore, to attempt to develop a photographic null method.

THEORY.

The absorption of light by a medium follows the exponential law; that is, the first layer absorbs a certain portion of the transmitted radiation, the next equal layer absorbs the same portion of what remains, and so on. This law is expressed by the following equation:

$$I = I_o e^{-kd}$$

where

I_o = initial intensity of light.
I = intensity of light after transmission.
k = coefficient of absorption.
d = thickness of absorbing medium in centimetres.
e = Napérian base.

This law applies, of course, only to homogeneous media and monochromatic radiation. The coefficient of absorption k varies in general with the wave length.

Radiation is not only partly absorbed in passing through a medium, but when it strikes a medium of different density, it is also partly reflected. Thus when light strikes glass, a small percentage is reflected at the air-glass surface, and also at the glass-air surface. This latter reflected light will be partly reflected back and forth between the faces of the glass, but since only a small

fraction (about 5 or 10 per cent.) is reflected at any one time, the two reflections mentioned first are the only ones that need be considered. When the glass is comparatively thin the amount of reflected radiation is quite large in comparison with the absorbed radiation, and the value of k calculated from the above formula will be considerably in error. The value of k thus calculated may be called the *apparent coefficient of absorption.* In order to determine the *true* or *absolute coefficient of absorption* two different thicknesses of the same kind of glass should be used as follows:

Let r_1 = fraction of incident radiation reflected at the air-glass surface.

Then $(1-r_1)$ = fraction of incident radiation passing into the glass, and $(1-r_1)e^{-kd}$ = fraction of incident radiation reaching glass-air surface.

r_2 = fraction of radiation reflected at glass-air surface.

Then $(1-r_2)\ (1-r_1)e^{-kd}$ = fraction of incident radiation passing out of glass.

Therefore $I = mI_0e^{-kd}$

where $m=(1-r_1)\ (1-r_2)$, and is constant for varying thicknesses of the same kind of glass, neglecting multiple reflections within the glass itself.

Let d_1 and d_2 = the thickness in cm. of two samples of the same kind of glass.

I_1 and I_2 = the respective intensities of the radiation after passing through these samples.

then $I_1 = mI_0\, e^{-kd_1}$

$$I_2 = mI_0\, e^{-kd_2}$$

Dividing $\dfrac{I_1}{I_2} = e^{-k(d_1-d_2)}$

$$\operatorname{Log}_e \frac{I_1}{I_2} = -k(d_1-d_2)$$

Hence $k = \dfrac{\log_e \dfrac{I_1}{I_2}}{d_2-d_1}$

The measurement of d_1 and d_2 involves no difficulty, but the determination of l_1 and l_2 means that the intensity of ultra-violet must be measured quantitatively.

METHODS FOR MEASURING THE INTENSITY OF INVISIBLE RADIATION.

There are several means for determining the absorption of the ultra-violet light in a given medium. The radiometer, thermopile, and bolometer theoretically can give results with an uncertainty of 0.1 to 1.0 per cent. However, temperature changes,

air currents, magnetic disturbances, calibrations and general inconvenience of manipulation make it desirable in many cases to employ the photographic method, which, while not so sensitive, may give more positive and reliable results. The uncertainty of results in photographic spectrophotometry is usually stated to be about 5 per cent., or with special precautions, somewhat better. From the practical standpoint this degree of accuracy is quite sufficient. Furthermore, photography offers several distinct advantages over any other method:

1. Less adjustment is required than in any other method. As comparative exposures can be made within the short space of two minutes, the errors resulting from a change of conditions are very small.

2. Extremely faint lines can be detected and measured. This seems to be difficult to accomplish with other methods.

3. There can be no question as to the exact wave length that is being measured, for the spectral lines as they appear on a photographic plate are very definitely known.

4. The photographic plate gives a permanent record of the test.

THE METHOD EMPLOYED IN THIS INVESTIGATION.

On account of the many variables, such as temperature, time exposure and development, uniformity of emulsion, handling of the plate during development, etc., all of which enter into photography to a greater or less degree, it was at once decided to employ a null method. The intention was to interpose the absorbing medium in a beam of light of constant intensity and expose a photographic plate for a given length of time. The medium was then to be removed and the intensity reduced by a known amount. Immediately another exposure was to be made for the same length of time on the adjacent portion of the plate. Since these exposures could usually be made within two minutes there would hardly be any change of conditions during the process of obtaining the spectrograms, and since the exposures were to be made on the same plate, practically no errors would be introduced due to the emulsion and the development.

By making several exposures as above with various reduced intensities of the incident beam, a very close watch could be obtained between two adjacent images of the same spectral line,

and a fairly close estimate of the absorption obtained for that particular wave length. For example, if the effect produced by the original beam of light after passing through the medium were the same as the effect produced by the beam when striking the plate after a reduction of 30 per cent. in intensity, the absorption of the medium would be 30 per cent. for that particular wave length.[1]

The problem now resolved itself into two parts: (1) to determine the equality of the densities of the two adjacent images on the photographic plate, and (2) to reduce the incident beam of light by a known amount.

With regard to the first part it might be in order to review briefly the characteristics of the photographic plate in so far as they affect the problem at hand. The density D of a photographic plate is a measure of the amount of metallic silver reduced in the film. If the ratio $\frac{I_i}{I_t}$ of the incident to the transmitted light is determined by means of a spectrophotometer or a microphotometer, the value of the density may be defined by the formula,—

$$D = \log_{10} \frac{I_i}{I_t}$$

If the densities of the plates exposed for equal lengths of time be plotted against the logarithms of the incident intensities of light, the relations shown in Fig. 1 will in general hold.

The curve is seen to consist of three distinct parts: An initial period *ab* during which the density increases very slowly with increase of intensity (under exposure); an intermediate period *bc* where the relation is approximately linear (correct exposure); and a final period *cd* where increase of intensity causes but slight increase of density (over exposure). The straight-line portion of the characteristic curve has been made use of in most of the quantitative photographic work up to the present time. It means that the so-called scale of gradation should be determined for each plate that is used for making comparative exposures. Other-

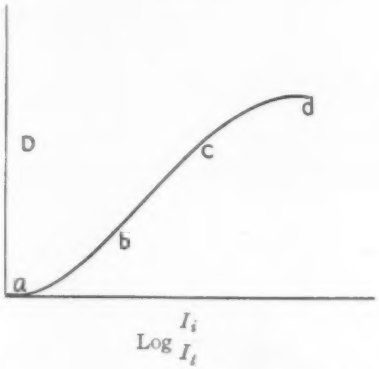
[1] Since the completion of this work the writer's attention has been called to an article appearing in *Comptes Rendus*, December, 1913, page 1065, where G. Ribaud describes a photographic null method for determining the absorption of ultra-violet by bromine vapor. For reducing the intensity of the incident beam of light he used two nicols.

wise errors due to development and non-uniformity of plates would be introduced. Such a procedure is necessarily long and tedious. In the balanced or null method, however, only a qualitative determination of this range of gradation need be made in order that the variation in density may be as great as possible for a given variation in intensity.

The equality of two adjacent images can thus be more easily judged. It is important to note that long development magnifies the range of densities corresponding to a given range of incident intensities.

Several different kinds of dry plate have been used in photo-

FIG. 1.



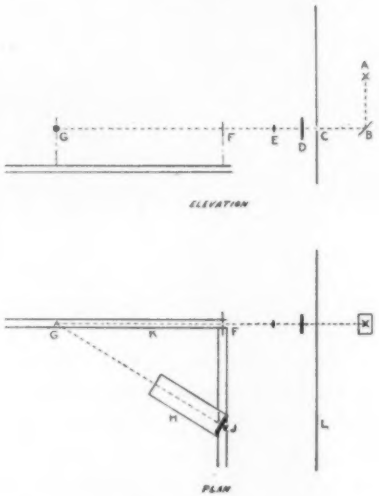
graphic photometry. The most commonly used are Seed's Gilt Edge 23, 26, and 30. For the work of the present investigation, No. 30 was found to be the most satisfactory; it is quite slow in action and is not affected above the *D* line. For work in the visible spectrum the Cramer Tri-Color plate was used. The Wratten Pan-Chromatic and M plates are also recommended. These pan-chromatic plates are ordinary plates which have been treated with certain dyes called sensitizers.

Ultra-violet light acts chiefly on the surface of the plate, while the visible light acts more evenly throughout the layer. In any case it is best to use a metol-hydro-quinone developer, which is noted for its action on the whole emulsion at once, depositing black silver throughout the layer, rather than only on the surface as in the case of other developers.

OPTICAL ARRANGEMENTS.

Now in order to study the absorption of definite wave lengths, it is necessary to have a constant source of ultra-violet light, and to disperse a beam of this light into its spectrum. Furthermore, the optical system must be as transparent as possible to ultra-violet light. This means that only fluorite or quartz lenses and prisms can be used. There are two ways of obtaining the spectrum for photographic processes. The first one is to use a spectrograph with its quartz prism. The instrument is very compact and

FIG. 2.



Arrangement of apparatus.

easy to manipulate. However, the Rowland concave grating method offers several distinct advantages. In the first place it gives greater dispersion and in the second place the distances between lines as measured on the plate are proportional to the differences in wave length of these lines.

For these reasons it was decided to use the concave grating method. The arrangement of apparatus is shown in Fig. 2, which is drawn to scale. *A* is the source of ultra-violet, namely, a 220-volt quartz mercury lamp, which was found to operate with great constancy after twenty minutes; *B* is a speculum metal

plane mirror for directing the beam of light horizontally. Speculum metal does not reflect the extreme ultra-violet very well, but as glass absorbs this extreme radiation totally, this failing was of no consequence. *L* is a wooden partition between the lamp compartment and the room containing the grating. *C* is a small hole in this partition, which contains an ordinary camera shutter with operating bulb. By this arrangement and a stop watch the time of exposure could be accurately observed within one-fifth of a second. *D* is a holder for the absorbing medium. *E* is a 1¼ inch diameter quartz lens with a principal focal length of 8 inches. By this means the image of the quartz burner could be sharply focused on the adjustable slit *F*. *K* is the usual track for maintaining the system in focus. *G* is a Rowland concave grating 3.3 cm. long by 2.2 cm. wide. The number of lines per inch is approximately 12,380 and the radius of curvature 1 meter. *H* is the camera box, *I* the photographic plate, in front of which is a partition with a horizontal slit ½ cm. high for the purpose of limiting the height of the spectral lines; and *J* is a slow-motion screw for the final adjustment of the focus.

THE ABSORBING SCREENS.

The second part of the problem, namely, reducing the intensity of the incident beam of light by a known amount, involved a little difficulty. The intensity could not be altered by varying the distance from the source, nor could an iris diaphragm be used on account of the resulting unequal illumination of the grating. The simplest and, at the same time, the most positive means of reducing the intensity was to interpose a square-woven wire screen in the beam of light. The resulting integral effect of light thus reduced in intensity was tested out in a preliminary way by using ordinary wire gauze sieves. The results were so encouraging that it was decided to make up a set of these screens giving a range in transmission of from 5 to 95 per cent. Upon consulting manufacturers' catalogues, it was found that the maximum per cent. transmission that could be obtained in any such screen was about 75, and the minimum about 20. A large assortment of samples of brass and copper wire gauze was obtained and transmissions roughly determined on a Lummer-Brodhum photometer bar. It was thus found necessary to make up special screens for trans-

missions below 20 per cent. and also for 70, 80, and 90 per cent. The low transmission screens were easily made by combining screens, but the high transmission screens required fine wire to be carefully spaced and soldered on a rigid frame. All the available gauzes were also soldered on a brass ring two inches in diameter in order to insure flatness and to facilitate handling. The absorptions of these screens were then very carefully obtained on the photometer bar. The results are shown in Table I.

TABLE I.

MESHES PER INCH.	PER CENT. TRANSMISSION.
Combination of screens	3.06
Combination of screens	9.13
100	19.2
30	22.8
140	29.9
50	33.5
80	36.0
40	38.6
20	47.2
10	53.0
24	60.2
10	71.4
10	80.1
10	91.6

The reason that screens of the same mesh did not give the same per cent. transmission is of course because of the different diameters of the wire. It is best to have the number of meshes per inch 20 or over, in order to give a better integral effect. Preliminary tests showed that, in order to insure uniform density of the image on the plate, it was best to incline the wires 15 to 30 degrees from the vertical (keeping the screen always perpendicular to the beam of light), otherwise it was often possible to observe streaks on the images. It is also desirable, in combining two or more screens, to place the screens some distance apart.

DESCRIPTION OF THE TESTS.

Preliminary Tests.—The mirror and quartz lens were adjusted so as to give a vertical image (about 3 mm. wide) of the quartz tube on slit *F*. The grating was then adjusted by means of slow-motion screws to give uniform illumination of the spectral

lines on a ground glass at *I*. To secure the final adjustment of the images of the spectral lines the slit *F* was first moved on the track *K* to give approximate focus, the final focus being obtained by means of the slow-motion screw *J*.

Photographs were taken using a slit width of 0.10 mm. for the purpose of testing the adjustment of the mounting. The results showed good optical arrangements, but in the case of exposures of over 30 seconds there seemed to be a faint continuous spectrum (see Plate IV)[2] which apparently was not due to dispersion but to light reflected from the bright parts of the grating as well as from grating lines themselves. Black paper fixed over the grating fixtures eliminated a considerable part of this stray light, but not all. However, this trouble was of no great consequence.

In order to map the spectrum the distance between known lines on the plate were carefully measured. The mean of several measurements showed that each centimetre was equivalent to 20.02$\mu\mu$. With the aid of Table II, which was compiled from the

TABLE II.

ARC SPECTRUM LINES OF MERCURY.

Wave Lengths in $\mu\mu$.

709.23	404.67	292.54
708.24	398.40	289.36
690.81	390.65	275.98
671.66	366.35	275.29
623.46	366.29	269.89
615.26	365.48	265.54
612.37	365.03	265.38
607.30	339.05	265.22
588.91	334.15	257.63
579.05	313.19	253.57
576.96	313.16	253.49
546.07	312.58	248.39
491.64	302.75	248.28
435.86	302.56	248.21
434.76	302.34	246.41
407.80	302.15	244.69
.....	295.74	239.94
.....	.....	237.84
.....	.....	230.27

[2] In the appendix will be found a number of typical spectrograms.

latest data, it was then a very simple matter to identify any line on a spectrogram.

A large number of spectrograms were taken in order to obtain the absorption of various samples of glass qualitatively; that is, to determine the minimum wave length that could get through. It was found that in most cases an exposure of five or ten seconds was sufficient to bring out nearly all the lines, but in many instances it was necessary to expose for 60 or even 120 seconds in order to bring out the minimum line very faintly.

This is a point that does not seem to have been greatly emphasized by other workers in this field, and is probably the reason why so many glasses are said to be better than they are actually. Another point to be looked out for in the matter of obtaining the minimum wave length transmitted, is the proper width of slit. With a slit width of 1 mm. the excessive stray light at long exposures obliterated any faint lines that would show with smaller slit widths. In order to secure the best results the slit width should never be more than about 0.3 mm. when dealing with very faint lines.

Absorption Tests.—For making the quantitative absorption tests it was decided to use some ordinary plate glass. A dozen pieces (2 inches x 4 inches) of such glass (marked "American") were cut from the same plate in order to insure uniformity of test specimen in case of breakage; also to insure homogeneity in the case of varying thickness.

The receipt used in making this glass was as follows:

Sand (Ottawa)	100
Salt Cake	38
Lime Stone	28
Carbon	2.5

The transmission of a single thickness of this glass in the visible spectrum of a tungsten lamp burning at 1.25 watts per candle was found on the photometer bar to be 90.2 per cent.

First of all the glass was tested for the minimum wave length transmitted (see Plate XI). The absorption of the various wave lengths was obtained in the following way:

The initial intensity of the beam of light was reduced either by throwing the image off the slit, or by interposing an absorbing screen. As the intensity was kept constant throughout any given

test, no further account need be taken of this reduction in intensity except as a matter of record. It was found necessary to reduce the intensity in order to increase the time of exposure in the very strong lines to 5 or 10 seconds, so as to minimize the error due to observing the time of exposure.

Next the camera box *H* was slid along the track until the desired part of the spectrum was thrown on the photographic plate. The test specimen of glass was interposed in the beam of light and a series of exposures of varying time with one mm. slit was made in order to determine for each line the correct time of exposure to give a rather faint image of the line so that any change in intensity would cause considerable change in density.

After a study of the proper time of exposure had been made for each important line, a series of spectrograms were taken, keeping the time of exposure constant, and substituting for the test specimen a series of absorbing screens in order to determine approximately the range of absorption for each prominent wave length. When the glass was interposed in the beam of light care was always taken that the path of the reflected beam coincided with the path of the incident beam so as to be sure that the image on the slit was not displaced.

With a knowledge of the proper time of exposure and the approximate absorption for each wave length it was then merely a matter of taking some final spectrograms of the glass and absorbing screens.

The above procedure was carried out for a single thickness of "American" glass, and then for a triple thickness obtained by clamping three single thicknesses together. In order to eliminate reflection at the inner faces, a few drops of chloral hydrate in a solution of glycerine was placed between the glasses. This solution having practically the same index of refraction as ordinary glass, eliminated the effect of the inner faces and gave a practically homogeneous medium.

RESULTS OF TESTS.

Table III gives the results of the absorption tests on "American" plate glass. The first horizontal line in each set of data gives the wave length; the vertical columns, the range of per cent. of transmission (the minimum always being given in the

first space) and the last horizontal column in each set, the per cent. transmissions as estimated by the eye from the final tests. At first, a binocular microscope was used, but this arrangement offered so little improvement that it was abandoned in favor of the naked eye.

TABLE III.

RESULTS OF TESTS—OBSERVED DATA. SINGLE THICKNESS OF GLASS.

No. Plate	492	436	408	405	391	365	334	313	302
41	.....	.....	80–100	.....	80–100	50–100	39–53	.....	....
44	.....	.....	.....	.....	.....	.....	.....	min.	0
49	.....	80–100	80–100	80–100	80–100	60–100	39–47	.....	....
52	.....	–92	–92	–92	.....	–92	.....	.....	....
53	.....	–92	–92	–92	–92	–92	.....	.....	....
54	.....	80–	80–	80–	.....	71–80	.....	.....	....
55	.....	80–92	.....	80–92	.....	71–80	.....	.....	....
56	.....	.....	.....	.....	.....	.....	.....	0.3–3.0	0
62	.....	80–92	80–92	80–92	80–92	71–92	39–47	.....	....
Est'd.	.....	88	88	86	86	77	46	1.5	0
Triple Thickness of Glass.									
66	.....	47–80	60–71	47–80	.....	47–71	.....	.....	....
71	–80	60–80	60–80	60–80	.....	53–60	9–20	.....	....
72	80–85	80–	70–80	80–	–70	53–60	.....	.....	....
Est'd.	80	80	77	80	67	57	12	.....	....

TABLE IV.

CALCULATED RESULTS.

Wave Length	l_1	l_2	k_1	k_2	k	$1-m$
320	.013	.077	4.45	7.53	2.80	0.800
325	.035	.170	.....	.....	2.48	.....
330	.075	.315	2.65	3.38	2.25	.320
335	.135	.482	2.04	2.13	1.96	.....
340	.218	.565	1.55	1.68	1.50	.060
350	.367	.671	1.02	1.17	.947	.....
360	.490	.743	.728	0.872	.654	.071
380	.675	.832	.402	0.540	.328	.069
400	.757	.868	.284	0.416	.220	.061
420	.790	.878	.240	0.378	.164	.071
440	.800	.880	.228	.374	.150	.074

The plotted transmissions are shown in Fig. 3.

In Table IV are shown the calculated results derived by using the values of I_1 and I_2 (obtained from these transmission curves) in the formulæ on page 313.

FIG. 3.

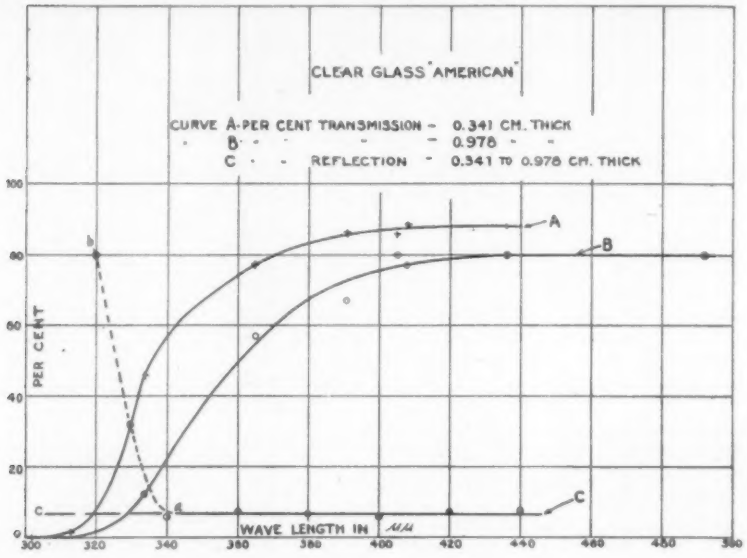
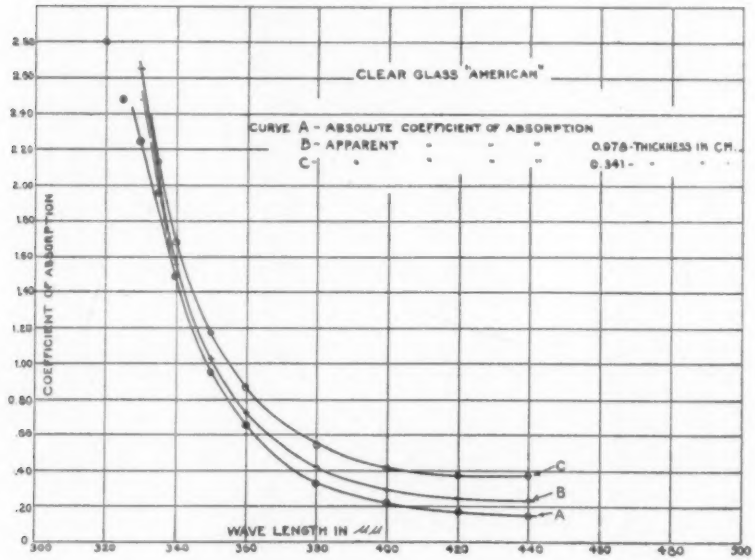

CLEAR GLASS "AMERICAN"
CURVE A-PER CENT TRANSMISSION - 0.341 CM. THICK
B - - - - 0.978 - -
C - - REFLECTION - 0.341 TO 0.978 CM. THICK
PER CENT
WAVE LENGTH IN μμ
A
B
C

FIG. 4.


CLEAR GLASS "AMERICAN"
CURVE A - ABSOLUTE COEFFICIENT OF ABSORPTION
B - APPARENT - - - 0.978-THICKNESS IN CM.
C - - - - 0.341 - - - -
COEFFICIENT OF ABSORPTION
WAVE LENGTH IN μμ
A
B
C

$$k = \frac{\log_e \frac{I_2}{I_1}}{d_1 - d_2} \text{ (Absolute coefficient of absorption).}$$

$$k_1 = \frac{\log_e \frac{I_0}{I_1}}{d_1} \text{ (Apparent coefficient for thick glass).}$$

$$k_2 = \frac{\log_e \frac{I_0}{I_2}}{d_2} \text{ (Apparent coefficient for thin glass).}$$

$\log_e m = \log_e \frac{I_1}{I_0} + kd_1$ (Where m equals the fraction of radiation remaining, subtracting amount lost due to reflections).

In these formulæ I_o is taken as unity. Fig. 4 shows the plotted calculated values of the absorption coefficients and curve C (Fig. 3) shows the plotted values of the per cent. reflection.

DISCUSSION OF RESULTS.

As was to be expected from the previous theoretical considerations, the apparent coefficient of absorption for the thin glass was greater than for the thick glass, and at very high absorptions these coefficient curves appeared to merge into each other. The broken part of the curve A will be referred to below.

The reflection curve C (Fig. 3) is dotted below wave lengths 340 on account of the fact that the relative values of the observed transmissions in this region are probably in great error. For example, it was found that the per cent. of transmission in the thin glass for the 313th line lay between 0.3 and 3.00 and was roughly estimated at 1.5. In the case of thick glass this line was so faint that no estimate could be obtained. Consequently, the ratio of the transmissions was indeterminate at this point, and not very accurate at other points of this end of the transmission curves.

Now the reflection curve is practically a straight line throughout the part of the spectrum that was measured quite accurately for absorption. This fact showed that there was no selective reflection in this region, and since there are no data to show that glass reflects selectively any radiation which it can transmit, the straight part of this reflection curve was extrapolated as shown by the broken line *ac*. With the constant value .068 for $(1\text{-}m)$, and therefore 0.932 for m, the absolute coefficients k were calculated from the following formulæ:

FIG. 3.

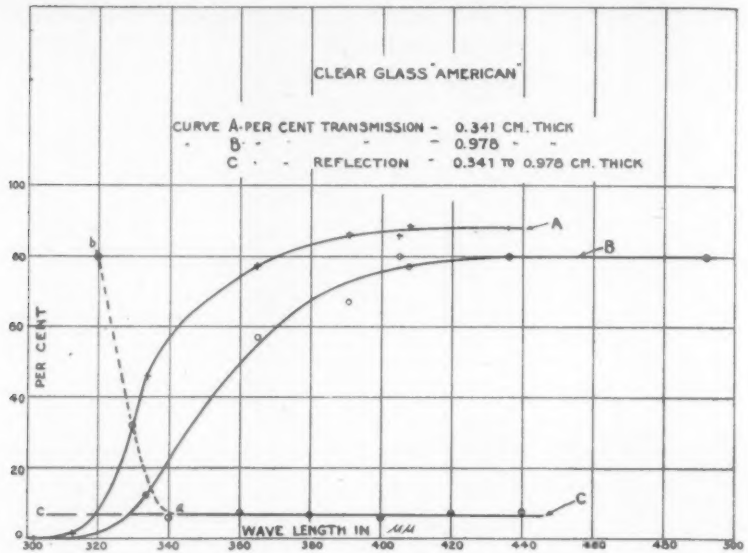
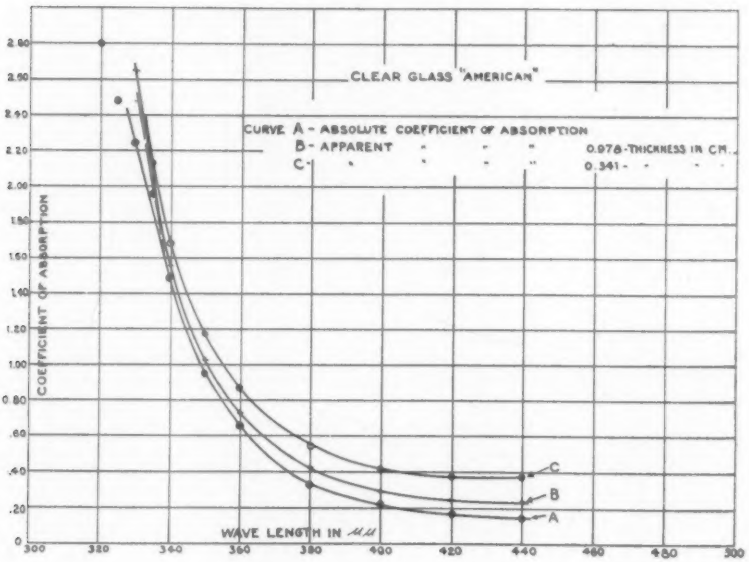

CLEAR GLASS "AMERICAN"
CURVE A-PER CENT TRANSMISSION - 0.341 CM. THICK
B - - - - 0.978 - -
C - - REFLECTION - 0.341 TO 0.978 CM. THICK
PER CENT
WAVE LENGTH IN μμ
A
B
C
100
80
60
40
20
0
300
320
340
360
380
400
420
440
460
480
500

FIG. 4.


CLEAR GLASS "AMERICAN"
CURVE A - ABSOLUTE COEFFICIENT OF ABSORPTION
B - APPARENT - - - 0.978-THICKNESS IN CM.
C - - - - 0.341 - - - -
COEFFICIENT OF ABSORPTION
WAVE LENGTH IN μμ
C
B
A
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
.60
.40
.20
0
300
320
340
360
380
400
420
440
460
480
500

$$k = \frac{\log_e \frac{I_2}{I_1}}{d_1 - d_2} \text{ (Absolute coefficient of absorption).}$$

$$k_1 = \frac{\log_e \frac{I_0}{I_1}}{d_1} \text{ (Apparent coefficient for thick glass).}$$

$$k_2 = \frac{\log_e \frac{I_0}{I_2}}{d_2} \text{ (Apparent coefficient for thin glass).}$$

$\log_e m = \log_e \frac{I_1}{I_0} + kd_1$ (Where m equals the fraction of radiation remaining, subtracting amount lost due to reflections).

In these formulæ I_0 is taken as unity. Fig. 4 shows the plotted calculated values of the absorption coefficients and curve C (Fig. 3) shows the plotted values of the per cent. reflection.

DISCUSSION OF RESULTS.

As was to be expected from the previous theoretical considerations, the apparent coefficient of absorption for the thin glass was greater than for the thick glass, and at very high absorptions these coefficient curves appeared to merge into each other. The broken part of the curve A will be referred to below.

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Now the reflection curve is practically a straight line throughout the part of the spectrum that was measured quite accurately for absorption. This fact showed that there was no selective reflection in this region, and since there are no data to show that glass reflects selectively any radiation which it can transmit, the straight part of this reflection curve was extrapolated as shown by the broken line ac. With the constant value .068 for $(1\text{-}m)$, and therefore 0.932 for m, the absolute coefficients k were calculated from the following formulæ:

$$k = \frac{\log_e m - \log_e \frac{I_1}{I_0}}{d_1}$$

$$k = \frac{\log_e m - \log_e \frac{I_2}{I_0}}{d_2}$$

These corrected values of k are shown in Table V. Since both I_1 and I_2 were considerably in error, two different values of k were found, one for each thickness of glass. Furthermore, this correction was obtained by correcting only the m term of the above formulæ. Hence the results would still be in error, but by taking the averages the doubtful end of the absolute coefficient of absorption curve could be better drawn in as shown by the broken lines in Fig. 4.

TABLE V.

CORRECTED VALUES OF k.

Wave Length	k (0.341 cm.)	k (6.978 cm.)	Average k
320	7.32	4.38	5.85
330	3.18	2.58	2.88
335	1.93	1.97	1.95
340	1.47	1.48	1.48

As to the accuracy of the observed data, it can be stated that the eye was able to detect without difficulty a 10 per cent. change in the intensity; and that, therefore, with sufficient screens the estimated transmissions were in error not more than 5 per cent. It was very likely that a microphotometer would decrease this figure considerably. As the source of the ultra-violet did not fluctuate more than 1 per cent. within the space of three minutes, and as the time of exposure was correct, within 1 per cent., these errors were comparatively too small to have any effect on the results.

SUMMARY.

1. The photographic null method as described gives coefficients of absorptions easily to within 5 per cent.

2. To secure the best results the intensity of the transmitted beam of light and the time of exposure should be such as to give a light gray image on the photographic plate.

3. The time of exposure should be 10 seconds or over.

4. No shadows of the wires of the screens should appear on the grating.

5. In working with very faint lines the slit width should not be more than 0.3 mm. nor less than 0.2 mm.

In conclusion, the authors wish to express appreciation to Dr. J. P. Jackson, Commissioner of Labor of Pennsylvania, and Dean of the School of Engineering of The Pennsylvania State College, for aid given in starting these experiments and interest taken in the results obtained.

APPENDIX.

In this appendix are shown a number of typical spectrograms (Plates XIII, XIV, and XV) for obtaining absorptions quantitatively, as well as several spectrograms for illustrating the transparency of various colored glasses to ultra-violet light. It must be remembered that no final conclusions can be drawn from the prints, for it is practically impossible to reproduce the faintest lines of the negative. In all cases the results were obtained from the photographic plate and never from a print.

Plate I is a spectrogram of the mercury arc spectrum showing the principal lines (in $\mu\mu$) for reference. This plate was obtained from the quartz mercury lamp without its glass globe, and wherever "quartz" is mentioned as the absorbing medium, it means that the spectrogram was obtained from the bare mercury arc; *i.e.*, with the quartz tube as the only absorbing medium.

Plates II and XI show how important it is to increase the time of exposure until no more lines appear on the spectrogram. With the apparatus used it was found that an exposure of 120 seconds was sufficiently long to bring out the line of minimum wave length in all of the glasses tested, whether high or low in the transmission of visible light. In most cases, however, it was found that exposures of 30 or even 10 seconds were quite long enough.

For the sake of comparison the times of exposure in Plates XII *a*, *b*, *c*, and *d* were all 120 seconds. The data giving the per cent. transmission for tungsten light at 1.25 watts per candle was readily obtained by means of a flicker photometer. In looking over the data obtained, in regard to the minimum wave length

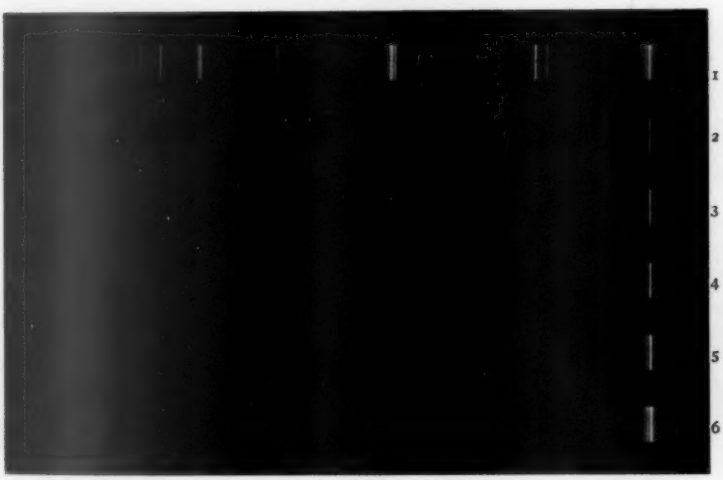
PLATE I.

Mercury arc spectrum (wave lengths in $\mu\mu$).

PLATE II.

1. Quartz..... 10 seconds.
2. "Nultra" glass..... 10 seconds.
3. "Nultra" glass..... 20 seconds.
4. "Nultra" glass..... 30 seconds.
5. "Nultra" glass..... 60 seconds.
6. "Nultra" glass..... 120 seconds.

PLATE III.

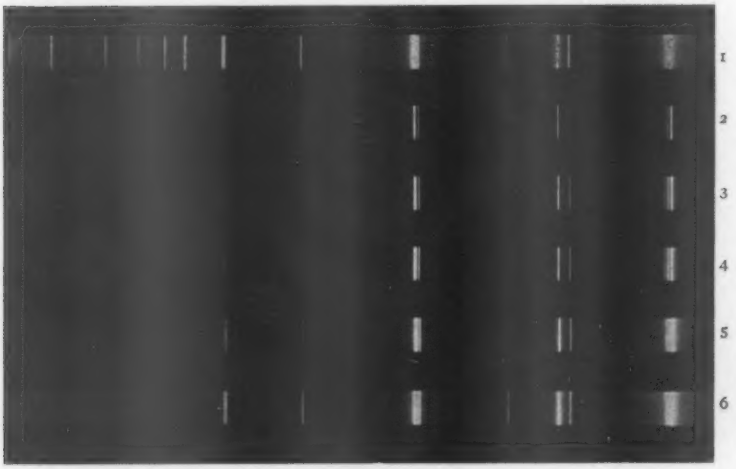


1. Quartz..... 10 seconds.
2. "Euphos" glass..... 10 seconds.
3. "Euphos" glass..... 20 seconds.
4. "Euphos" glass..... 30 seconds.
5. "Euphos" glass..... 60 seconds.
6. "Euphos" glass..... 120 seconds.

PLATE IV.

1. Quartz..... 30 seconds.
2. "Clear globe"..... 10 seconds.
3. "Clear globe"..... 20 seconds.
4. "Clear globe"..... 30 seconds.
5. "Clear globe"..... 60 seconds.
6. "Clear globe"..... 120 seconds.

PLATE V.

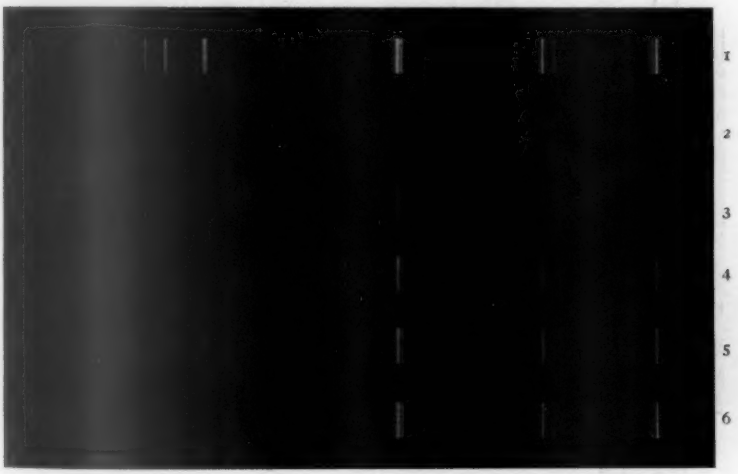


1. Quartz..... 30 seconds.
2. "Opalescent globe"..... 20 seconds.
3. "Opalescent globe"..... 30 seconds.
4. "Opalescent globe"..... 60 seconds.
5. "Opalescent globe"..... 120 seconds.

PLATE VI.

1. Quartz..... 20 seconds.
2. Orange yellow glass..... 2 seconds.
3. Orange yellow glass..... 10 seconds.
4. Orange yellow glass..... 30 seconds.
5. Orange yellow glass..... 60 seconds.
6. Orange yellow glass..... 120 seconds.

PLATE VII.

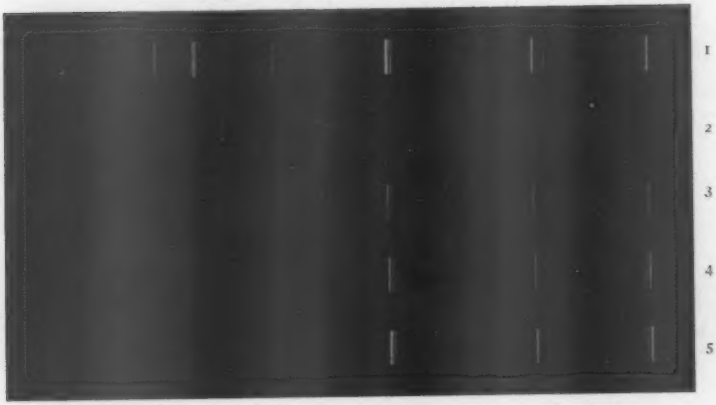


1. Quartz..... 20 seconds.
2. Very light yellow glass..... 2 seconds.
3. Very light yellow glass..... 10 seconds.
4. Very light yellow glass..... 30 seconds.
5. Very light yellow glass..... 60 seconds.
6. Very light yellow glass..... 120 seconds.

Plate VIII.

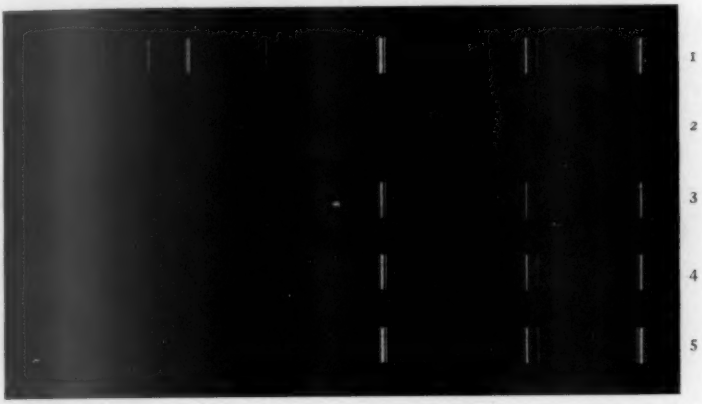
1. Quartz..... 20 seconds.
2. Blue glass..... 2 seconds.
3. Blue glass..... 30 seconds.
4. Blue glass..... 60 seconds.
5. Blue glass..... 120 seconds.
6. Blue glass..... 240 seconds.

Plate IX.



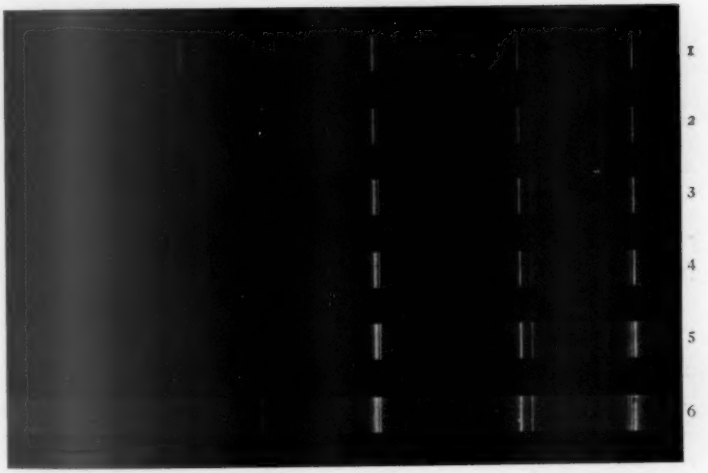
1. Quartz..... 20 seconds.
2. Faint pink glass..... 2 seconds.
3. Faint pink glass..... 30 seconds.
4. Faint pink glass..... 60 seconds.
5. Faint pink glass..... 120 seconds.

PLATE X.



1. Quartz..... 20 seconds.
2. Pink glass..... 2 seconds.
3. Pink glass..... 30 seconds.
4. Pink glass..... 60 seconds.
5. Pink glass..... 120 seconds.

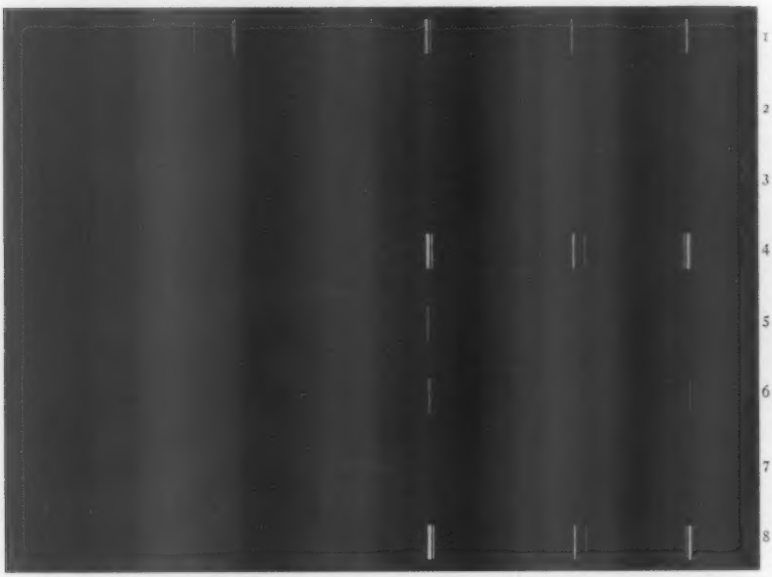
PLATE XI.



1. Quartz..... 10 seconds.
2. "American" clear glass..... 10 seconds.
3. "American" clear glass..... 20 seconds.
4. "American" clear glass..... 30 seconds.
5. "American" clear glass..... 60 seconds.
6. "American" clear glass..... 120 seconds.

transmitted, some very interesting results may be noted. For example, the faint pink of No. 4 transmits practically as much ultra-violet as the light blue of No. 20. Since both glasses have approximately equal transmissions for visible light, it was to be expected that the one nearer the red end of the spectrum would

PLATE XII *a*.

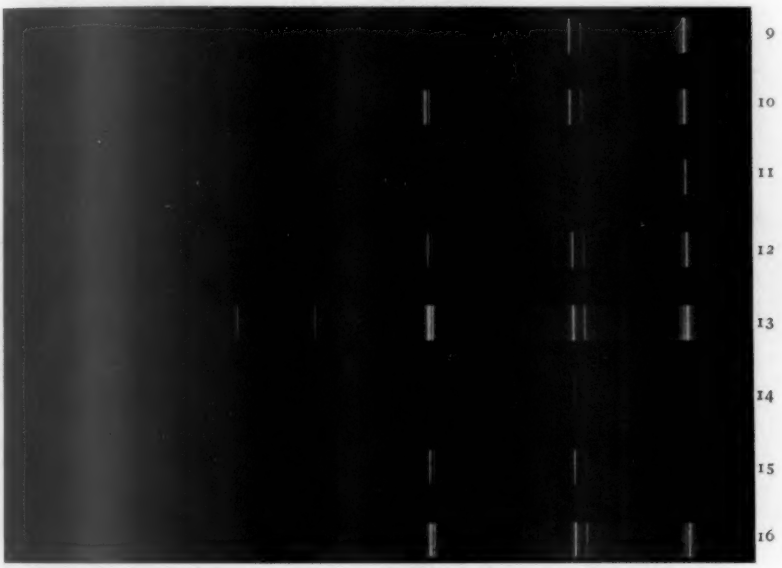


No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum Line. $\mu\mu$.
1.	Quartz	...	...
2.	Very deep red glass	4.1	...
3.	Red glass	17.8	...
4.	Faint pink	50.1	313
5.	Orange yellow	38.3	334
6.	Yellow	54.3	334
7.	Yellow ("Noviol")	78.0	546
8.	Very light yellow	78.8	313

cut off more ultra-violet, but this case clearly shows that no dependence may be placed on the color of the glass. Again, Nos. 7 and 8 of very nearly the same shade of yellow show widely different degrees of transmission of ultra-violet, the "Noviol" not transmitting even all of the visible wave lengths, while the other light yellow glass transmits as far down as the 313th line.

"Euphos" glass No. 11 cuts off the ultra-violet very sharply at 405, but "Nultra" glass appears to be better from a practical standpoint, for it barely transmits the 365th line (less than 1 per cent. by actual test) and absorbs only 15 per cent. of the visible light. The most remarkable glass of all is the orange-yellow of

PLATE XII *b*.



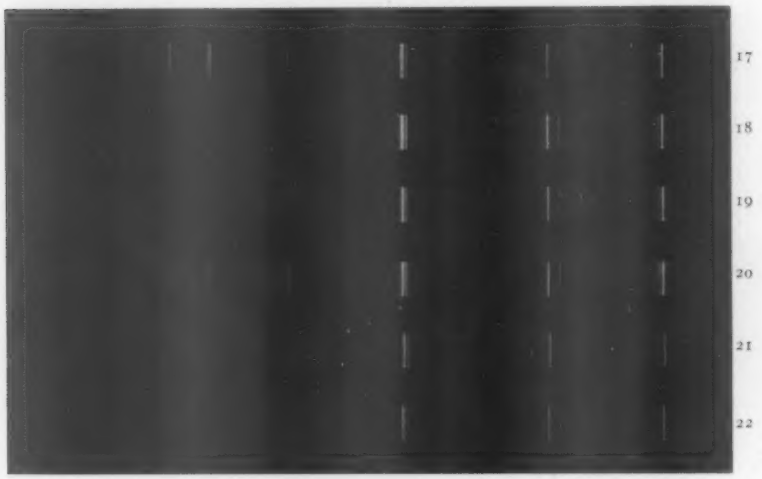
No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. $\mu\mu$
9.	Faint yellow ("Nultra")	85.0	365
10.	Faint yellow	84.3	313
11.	Yellow green ("Euphos")	72.0	405
12.	Yellow green	71.6	365
13.	Faint yellow green	82.5	302
14.	Very deep green	2.6	405
15.	Dark green	5.0	365
16.	Green	52.0	334

No. 5 (also see Plate VI), which appears to transmit selectively between 334 and 405, although its greatest transmission is at the other end of the spectrum.

Such examples as those cited above show very conclusively that the protective property of a glass cannot be judged by mere inspection.

The only safe conclusion in regard to the transmission of glasses for ultra-violet light is that there does not seem to be any glass which transmits below the 302th line, and which does not therefore cut out what is generally conceded to be the extremely harmful rays. However, until more conclusive data are

PLATE XII *c*.



No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. μμ
17.	Quartz	....	...
18.	Dark blue violet glass	2.5	334
19.	Blue	8.3	334
20.	Light blue ("Tungsten")	46.1	302
21.	Reddish purple	23.2	334
22.	Dark flesh color	44.3	334

obtained on this matter of the injurious ultra-violet light, every protective glass should be tested out at least qualitatively in the manner previously described, and those glasses which do not absorb almost completely the 365th line should be rejected.

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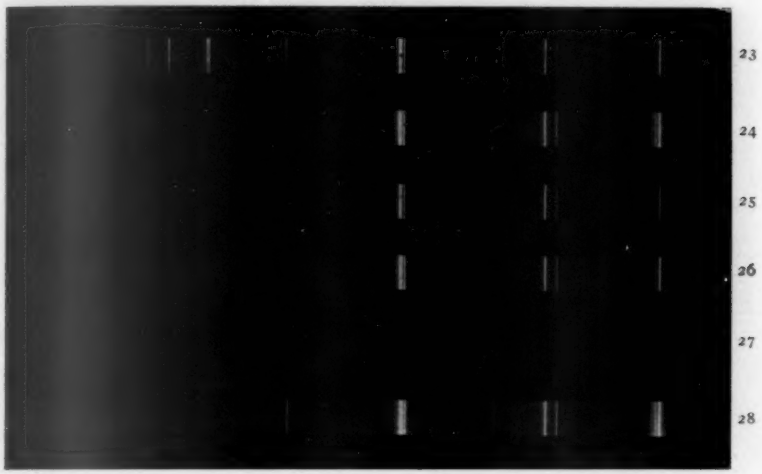
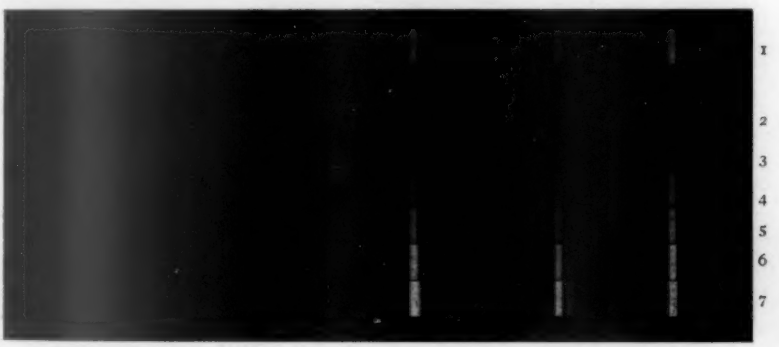
2. "Ultra-Violet Radiation from Ordinary Illuminants," M. Luckiesh, *Electrical World*, June 15, 1912.

PLATE XII *d*.



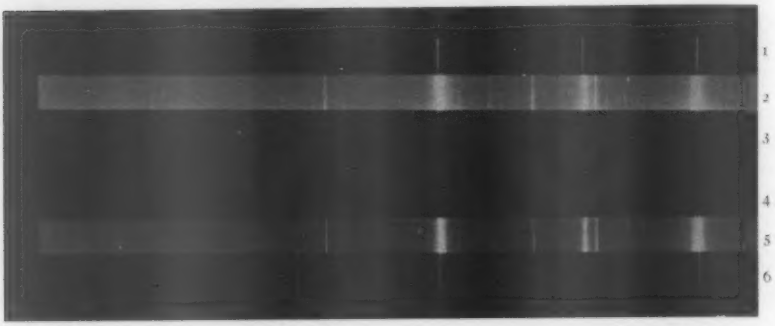
No.	Absorbing Medium.	Per cent. Transmission for Tungsten light at 1.25 w. p. c.	Minimum line. $\mu\mu$
23.	Quartz	....	...
24.	Light flesh color	73.8	334
25.	Dark gray	15.3	334
26.	Medium gray	36.8	334
27.	Ground glass	50.5	365
28.	Clear glass ("American")	90.2	313

PLATE XIII.



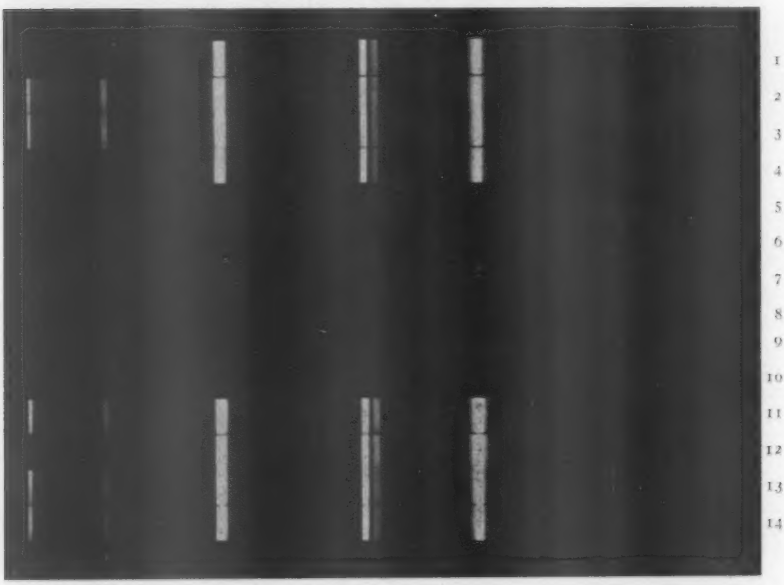
1.	Quartz	30 seconds.
2.	"American" glass	5 seconds.
3.	"American" glass	10 seconds.
4.	"American" glass	20 seconds.
5.	"American" glass	40 seconds.
6.	"American" glass	80 seconds.
7.	"American" glass	160 seconds.

Plate XIV.



1. 3.1 per cent. screen..... 120 seconds.
2. "American" glass..... 120 seconds.
3. 0.3 per cent. screen..... 120 seconds.
4. 0.3 per cent. screen..... 60 seconds.
5. Glass..... 60 seconds.
6. 3.1 per cent. screen..... 60 seconds.

Plate XV.



1. 3 "American" glasses..... 10.0 seconds.
2. 80 per cent. screen..... 10.2 seconds.
3. 71 per cent. screen..... 10.0 seconds.
4. 3 "American" glasses..... 10.0 seconds.
5. 80 per cent. screen..... 5.0 seconds.
6. 3 "American" glasses..... 5.0 seconds.
7. 71 per cent. screen..... 5.0 seconds.
8. 60 per cent. screen..... 5.0 seconds.
9. 3 "American" glasses..... 5.0 seconds.
10. 53 per cent. screen..... 5.0 seconds.
11. 71 per cent. screen..... 60.0 seconds.
12. 3 "American" glasses..... 60.0 seconds.
13. 60 per cent. screen..... 60.0 seconds.
14. 53 per cent. screen..... 60.0 seconds.

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OCCURRENCE OF ALDEHYDES IN GARDEN AND FIELD SOILS.*

BY

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THE discovery of salicylic aldehyde [1] in a soil from the Mt. Vernon gardens, led to a study of the extent to which material of this type would be likely to be encountered in soil investigations. In extending this study to many soils it was not feasible to examine large quantities of each soil, so that it was not possible to clearly demonstrate the identity of the aldehyde obtained, but it was possible to so treat a sample of soil as to obtain the compounds of an aldehyde nature contained therein, separated from compounds having non-aldehyde properties. This aldehyde material was tested, so far as the quantity permitted, for such reactions as are given by salicylic aldehyde; namely, coloration with ferric chloride, and the general aldehyde reactions with fuchsine reagent. In all cases the aldehyde was subjected to the physiological test as to its effect on plant growth, using wheat seedlings in the well-known manner. It will be well to describe here the exact procedure employed in extracting the aldehyde material from the soil and the manner of testing the same.

Twelve to sixteen pounds of soil were used in the examination for aldehydes. The soil was extracted with eight litres of a 3 per cent. solution of sodium hydroxide. The solution was stirred for six to eight hours, and, after settling, the liquid poured off. The alkaline extract was acidified with sulphuric acid and filtered from the so-called humus precipitate. The acid filtrate was shaken out with several portions of ether, the ether extracts combined and shaken with a concentrated aqueous solution of sodium bisulphite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combination with the sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid and air blown

* Communicated by Dr. Schreiner.

[1] Shorey, E. C., "Some Organic Soil Constituents," Bul. 88, p. 19, Bureau of Soils, U. S. Dept. Agric. (1913).

through to remove the sulphur dioxide liberated. This acidified solution, in which the aldehyde is now liberated from its combination with the bisulphite, was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation. There was obtained a small quantity of material, often resinous or oily in appearance.

This material was further purified by again taking up in water, extracting with ether, and the ether solution, after filtering, allowed to evaporate. Sometimes this operation was repeated. The purified residue contains the aldehyde material, if present.

This aldehyde material was treated with a small quantity of water. The aqueous solution is frequently colored, and on evaporation a yellow oil is often noticeable, as would be the case if salicylic aldehyde were present. The odor of the latter is also sometimes observed, although in other cases other odors are perceptible, suggesting other aldehydes.

The fuchsine reagent was added to a portion of the solution, and to another portion a small amount of ferric chloride was added. Salicylic aldehyde, as mentioned, gives a violet color with ferric chloride and a pink color with the fuchsine reagent. Where both these reactions were observed the soil was considered as containing aldehydes. While the nature of the material is not thereby definitely shown to be salicylic aldehyde, yet the manner of isolation with ether, extractions therefrom with sodium bisulphite, together with the reaction shown with the fuchsine reagent, show the material to be an aldehyde, and the physical character of fluidity and the reaction with ferric chloride make it quite probable that in most of these cases salicylic aldehyde was under consideration. The amount obtained did not permit of further identification than is here given, especially as the main object was to determine the physiological property of the extracted material.

The main portion of the material, remaining after making the above tests, was dissolved or mixed with 250 c.c. of pure distilled water and the resulting liquid used as a culture for wheat seedlings so as to test the physiological effect of the extracted material from the soil.

In order to study the presence of this aldehyde in soils a number of samples were tested. Included in this test were a

number of soils sent to this Bureau from time to time by interested gardeners and greenhouse growers. The soils submitted were garden and greenhouse soils, on which the owners had had trouble in producing vegetables or flowers. Often the soils had grown good crops, were intensively cultivated and heavily manured, and later failed. In this respect the conditions were similar to those on the Mt. Vernon soil, in which the salicylic aldehyde was first discovered. This soil had been used for growing flowers and garden plants for a long period of years, had been intensively cultivated and heavily manured for a long time, had failed to show further response to manure, had been declining in productivity, and had been shown to contain salicylic aldehyde in the investigation reported. It seemed, therefore, interesting to include soils which in some degree had had a similar history.

In addition to this adventitious examination of soil samples a similar survey was made with soils collected in the open field by the fieldmen of this Bureau under instructions furnished them. Accordingly samples of field soils were collected from various parts of the United States. A productive sample and an unproductive sample of the same soil type, either from the same field or at least in the same vicinity, were sent in for the investigation. The history of the soils as to crops grown, fertilization, drainage, etc., was secured so far as available.

The results of this examination for the occurrence of aldehyde compounds in soils include good and poor samples from many parts of the United States, comprising acid, neutral and alkaline soils, soils of different cropping, different texture, origin, drainage conditions, climatic conditions, etc. The results of the examination of these soils will now be given.

A total of 74 soils are described in the two following tables. Of these, 14 are garden and greenhouse soils which had failed to grow good crops, and 60 are field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. In this connection attention should again be called to the fact that the field samples were collected in pairs, one good and the other poor, of the same soil type and from the same field or locality.

These soils were all subjected to the method described for

obtaining aldehyde compounds from soils and the material thus obtained tested with the reagents mentioned. Five of the garden soils and twelve of the field soils gave an appreciable amount of aldehyde compounds when thus extracted, and this material gave positive reactions with the fuchsine reagent and with the ferric chloride. These soils are briefly described in Table I, together with the results obtained when the material was tested in the manner described with seedling wheat.

In Table II are given the remaining soils, which gave none or only an insignificant amount of extractive material when subjected to the method of obtaining aldehyde material from soils, nor did this extract give the reactions with the above reagents. We must conclude, therefore, that the aldehyde material—salicylic aldehyde or other aldehydes—is either absent or present in much smaller quantities in the soils of Table II than in the soils given in Table I.

From Table I it will be seen that the soil aldehyde is in every case harmful to growth, as shown in the next to the last column, and behaves in this respect like the Mt. Vernon soil (No. 1), which has been already more fully described and in which salicylic aldehyde of poisonous properties was demonstrated. The effect of the soil aldehyde was tested on wheat by growing the plants in water cultures. An experiment was made with the aldehyde in pure distilled water. The wheat was grown in water in culture jars holding 250 c.c. One jar contained pure distilled water, and the second contained the water in which was dissolved the aldehyde separated from the soil. The plants grew for two weeks. The aldehyde was quite harmful, reducing growth about 37 per cent. Another experiment was made, using a good nutrient solution with and without the substance. The aldehyde from the soil was extremely harmful, even in the good nutrient solution; the green weight of the plants was reduced 40 per cent. These experiments with the salicylic aldehyde extracted from the soil are shown in Fig. 1. The plants show the harmful effect of the substance on growth. It will be seen that both tops and roots in nutrient solution and in distilled water are badly affected by the presence of the salicylic aldehyde.

In Fig. 2 is shown the effect of this material from soil No. 2. This had been used for gardening and trucking for the

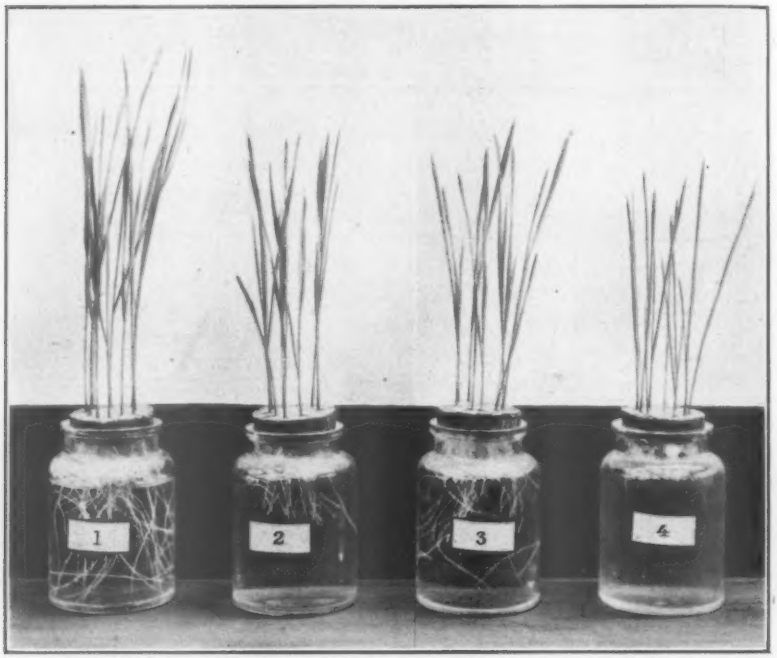
TABLE I.

Soils in Which Aldehydes were Demonstrated.

No.	Soil	Field record	Location	Crop on soil when sample was taken	Reaction of soil	Effect of extracted aldehyde material on growth of wheat	Notes
1	Garden soil, loam	....	Mt. Vernon, Va.	Flowers	Acid	Very harmful	Rich loam, well manured for over a century.
2	Garden soil, silt loam	....	Mechanicsburg, Pa.	Vegetables	Very acid	Very harmful	Poultry manure and commercial fertilizers for 70 years.
3	Garden soil, red loam	....	Orange, N. J.	Vegetables	Acid	Slightly harmful	Rich loam; declining. Heavy manuring ineffective.
4	Truck soil, red loam	....	Chester Co., Pa.	Truck crops	Alkaline	Very harmful	Commercial fertilizers and rotation. Trucked for 20 years. Crops now failing. Soil contains excess of salts (.15 per cent). Subsoil also contains aldehyde material.
5	Greenhouse soil, loam	....	Arlington, Va.	Flowers	Neutral	Very harmful	Heavily manured.
6	Memphis silt loam	Poor.	Lafayette Co., Miss.	Grass	Acid	Very harmful	Pasture 20 years. No fertilizer.
7	Aurora silt loam	Good.	Miller Co., Mo.	Corn	Slightly acid	Harmful	Manure occasionally. No fertilizers.
8	Norfolk very fine sandy loam	Good.	Pender Co., N. C.	Cotton	Acid	Harmful	Well manured, occasionally fertilized.
9	Norfolk very fine sandy loam	Poor.	Pender Co., N. C.	Cotton	Acid	Very harmful	No manure. 200 pounds commercial fertilizer.
10	Portsmouth silt loam	Poor.	Perquimans Co., N. C.	Corn	Slightly acid	Harmful	No manure. 200 pounds fertilizer.
11	Miami stony loam	Poor.	Oneida Co., N. Y.	Meadow	Acid	Harmful	Not fertilized.
12	Ontario loam	Poor.	Oneida Co., N. Y.	Corn	Neutral	Harmful	Stable manure.
13	Muskogee silt loam	Poor.	Muskogee Co., Okla.	Cotton	Acid	Harmful	No manure. No fertilizer.
14	Norfolk fine sandy loam	Poor.	Georgetown, S. C.	Corn	Acid	Harmful	Drainage poor.
15	Salt Lake clay	Poor.	Cache Co., Utah	Wheat	Alkaline	Harmful	Manured.
16	Dekalb silty clay loam	Good.	Preston Co., W. Va.	Grass	Slightly acid	Harmful	No manure; low-grade fertilizer used.
17	Dekalb silty clay loam	Poor.	Preston Co., W. Va.	Fallow	Slightly acid	Harmful	

last ten years, and had been manured each year with poultry manure and commercial fertilizers. The soil in the last two years produced poor vegetables and truck crops, and corn failed entirely. The soil is grayish yellow in color, is quite acid, and is low in organic matter. The separated aldehyde extract was harmful to growth of wheat seedlings, causing a decrease of 33 per cent.

FIG. 1.



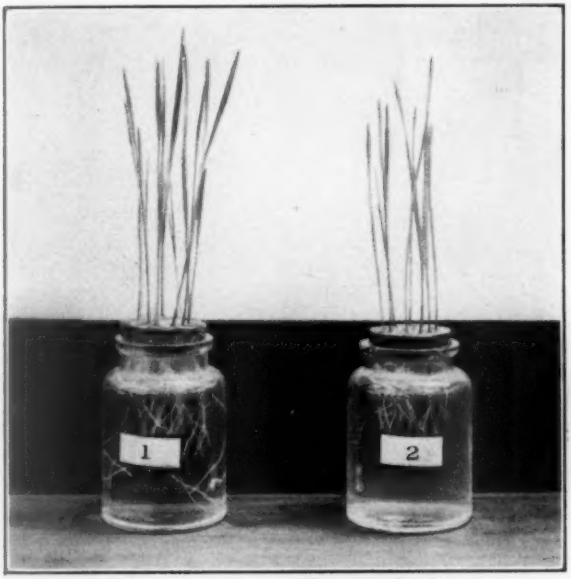
Effect of salicylic aldehyde extracted from Mt. Vernon garden soil on wheat seedlings. (No. 1, nutrient solution; No. 2, nutrient solution plus salicylic aldehyde; No. 3, distilled water; No. 4, distilled water plus salicylic aldehyde.)

In Fig. 3 is shown the effect of the aldehyde extract from a soil (No. 4, from Chester County, Pennsylvania) showing an alkaline reaction. This soil had been growing vegetables and truck crops for 20 years with frequent use of commercial fertilizers. Corn, cabbage, and cantaloupes had failed in certain sections of the field for the last two years, whereas formerly the soil grew excellent truck crops of all kinds. The soil and sub-

soil were quite alkaline to litmus paper, and both showed the presence of considerable aldehyde material. This reduced growth of the test plants by 26 per cent., both tops and roots being severely injured.

The heavily manured greenhouse soil (No. 5, Table I) is particularly interesting in that considerable aldehyde was found therein, whereas neither the raw soil (No. 8, Table II) nor similarly treated soil which had been used and then weathered

FIG. 2.

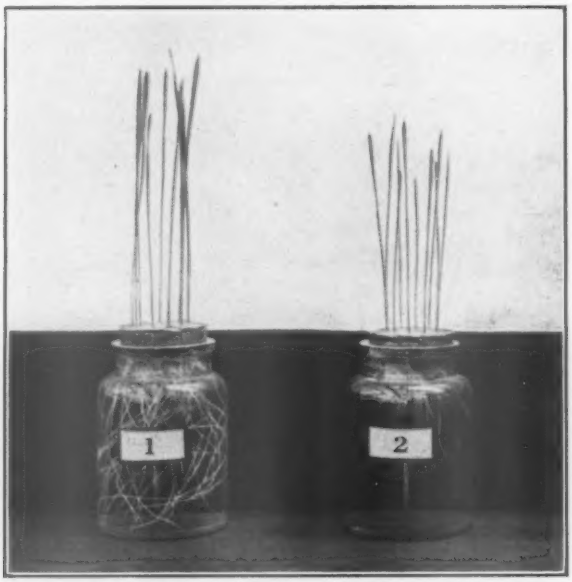


Effect of aldehyde extracted from garden soil (No. 2) from Mechanicsburg, Pennsylvania, on growth. (No. 1, distilled water; No. 2, distilled water plus aldehyde.)

for some time (No. 7, Table II) contained the harmful aldehyde material. This examination was made because the soil in question had been used on benches for floriculture and did not give good results. Soil No. 5, Table I, was a composite taken from two benches in the greenhouse where carnations and roses did not thrive. This contained aldehyde, which when tested with wheat seedlings gave reductions in growth of 35 per cent. Soil No. 7, Table II, had been previously used for greenhouse purposes and had been made in the same way by manuring heavily

the raw soil, but without experiencing any difficulty. Since then it had been in a pile outside for several months. At the time of testing no aldehyde could be found, nor was the residue obtained harmful to the seedling wheat. Soil No. 8, Table II, was some of the raw soil as it was hauled from the field previous to the incorporation of manure in preparation for greenhouse use. No aldehyde could be detected in this soil, nor did such residue as was obtained in this procedure show any harmful effect.

FIG. 3.



Effect of aldehyde extracted from a poor garden soil (No. 4) on wheat seedlings. (No. 1, distilled water; No. 2, distilled water plus aldehyde from garden soil.)

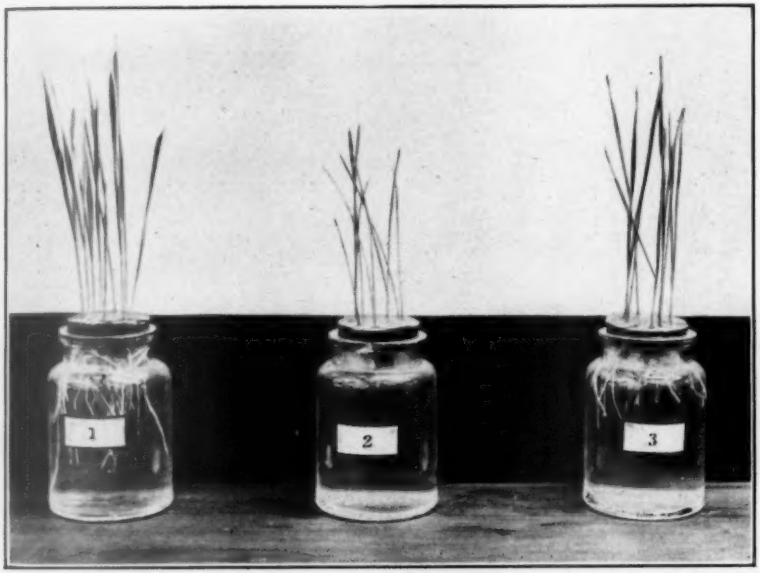
Soil No. 11, the poor sample of Miami stony loam, contained aldehyde, and the depressed growth obtained is shown in Fig. 4, together with the effect of the identically extracted good field sample. The latter showed no aldehyde reactions, but, as seen from the photograph, it was nevertheless, somewhat harmful, a fact which is recorded in Table II, under No. 41.

Soil No. 12, the Ontario loam, poor, from Oneida County, New York, together with its good companion sample, recorded

as soil No. 42, in Table II, presents an interesting story. In 1907 both fields were poor, unproductive soils. Both fields were manured heavily every year. One field responded to this treatment, the other did not.

The field represented by soil No. 42, Table II, grew corn in 1907, and produced a poor crop. In 1908 the field was manured and planted to oats, giving a good yield. It was manured every year after this. In 1909 and 1910 hay was grown with good

FIG. 4.



Effect of substance extracted from poor and good Miami stony loam on wheat plants. (No. 1, distilled water; No. 2, distilled water plus material from poor soil containing aldehydes; No. 3, distilled water plus material from good soil showing no aldehyde reactions.)

results, the largest crop being in 1910. In 1911 an excellent crop of corn was grown, and in 1912 oats were again grown with good yields.

The field represented by soil No. 12, Table I, was in meadow in 1907, and gave poor yields. In 1908 the field was manured and planted to corn, which failed entirely. It was manured every year after this without good results. In 1909 oats were planted, but made very little growth. In 1910 and 1911 grass was sown

TABLE II.

Soils in Which no Aldehydes could be Demonstrated.

No.	Soil	Field record	Location	Crop on soil when sample was taken	Reaction of soil	Effect of extracted material on growth of wheat	Notes
1	Garden soil, loam	....	Washington, D. C.	Flowers	.....	No effect	Heavily manured.
2	Garden soil, loam	....	Pittsburgh, Pa.	Flowers	Acid	.....	Manured. Responds to lime.
3	Garden soil, gray sandy loam	....	Philadelphia, Pa.	Garden crops	Acid	Harmful	
4	Garden soil, loam	....	Phœnixville, Pa.	Garden crops	Alkaline	No effect	Well manured. Salt content high.
5	Garden soil, gray loam	....	Philadelphia, Pa.	Garden crops	Alkaline	No effect	Drainage poor.
6	Garden soil, waxy black	....	Greene Co., Ind.	Garden crops	Acid	No effect	Responds to lime and potash fertilizers.
7	Greenhouse soil, loam	....	Arlington, Va.	Flowers	Neutral	No effect	Soil had weathered for months since it had been used in floriculture.
8	Greenhouse soil, raw soil	....	Arlington, Va.	.....	Acid	No effect	Poor raw soil used as basis for greenhouse soil No. 7, this table, and No. 5, table I.
9	Dark gray loam	....	Sanford, Florida	Citrus trees	Alkaline	No effect	Calcareous soil.
10	Tifton sandy loam	Good	Covington Co., Ala.	Corn	Slightly acid	Harmful	
11	Tifton sandy loam	Poor	Covington Co., Ala.	Corn	Slightly acid	Harmful	
12	Huntington fine sandy loam	Good	Pope Co., Ark.	Corn	Slightly acid	Slightly beneficial	
13	Huntington fine sandy loam	Poor	Pope Co., Ark.	Corn	Slightly acid	Slightly beneficial	
14	Decatur clay loam	Good	Chattooga Co., Ga.	Cotton	Acid	Not tested	
15	Decatur clay loam	Poor	Chattooga Co., Ga.	Cotton	Acid	Not tested	
16	Neosho silt loam	Good	Cherokee Co., Kan.	Wheat	Slightly acid	Beneficial	
17	Neosho silt loam	Poor	Cherokee Co., Kan.	Corn	Slightly acid	Beneficial	
18	Colby silt loam	Good	Jewell Co., Kan.	Corn	Neutral	Beneficial	
19	Colby silt loam	Poor	Jewell Co., Kan.	Wheat	Neutral	Beneficial	
20	Osage loam	Good	Greenwood Co., Kan.	Grass	Alkaline	Beneficial	
21	Osage loam	Poor	Greenwood Co., Kan.	Corn	Alkaline	Beneficial	
22	Dekalb silt loam	Good	Christian Co., Ky.	Clover	Neutral	No effect	
23	Dekalb silt loam	Poor	Christian Co., Ky.	Tobacco	Neutral	Slightly harmful	
24	Miami loam	Good	Genesee Co., Mich.	Grass	Slightly acid	Harmful	
25	Miami loam	Poor	Genesee Co., Mich.	Wheat	Slightly acid	Harmful	
26	Carrington silt loam	Good	Goodhue Co., Minn.	Barley	Slightly acid	Beneficial	
27	Carrington silt loam	Poor	Goodhue Co., Minn.	Grass	Slightly acid	Beneficial	
28	Memphis silt loam	Good	Lafayette Co., Miss.	Corn	Neutral	No effect	

29	Summit silt loam	Good	Cass Co., Mo	Oats	Not tested	No effect
30	Summit silt loam	Poor	Cass Co., Mo	Wheat	Not tested	No effect
31	Aurora silt loam	Poor	Miller Co., Mo	Millet	Slightly acid	No effect
32	Freehold loam	Good	Monmouth Co., N. J.	Grass	Slightly acid	Beneficial
33	Freehold loam	Poor	Monmouth Co., N. J.	Corn	Slightly acid	Slightly harmful
34	Dutchess silt loam	Good	Orange Co., N. Y.	Millet	Neutral	Slightly harmful
35	Dutchess silt loam	Poor	Orange Co., N. Y.	Grass	Neutral	Harmful
36	Chandler loam	Good	Ashe Co., N. C.	Corn	Neutral	No test
37	Chandler loam	Poor	Ashe Co., N. C.	Corn	Neutral	No test
38	Toxaway fine sand	Good	Ashe Co., N. C.	Grass	Slightly acid	Harmful
39	Toxaway fine sand	Poor	Ashe Co., N. C.	Grass	Slightly acid	Harmful
40	Portsmouth silt loam	Good	Perquimans Co., N. C.	Cotton	Slightly acid	Harmful
41	Miami stony loam	Good	Oneida Co., N. Y.	Corn	Acid	Slightly harmful
42	Ontario loam	Good	Oneida Co., N. Y.	Oats	Neutral	Slightly harmful
43	Muskogee silt loam	Good	Muskogee Co., Okla.	Peanuts	Acid	Beneficial
44	Berks shale loam	Good	Lehigh Co., Pa.	Grass	Slightly acid	No effect
45	Berks shale loam	Poor	Lehigh Co., Pa.	Grass	Slightly acid	No effect
46	Norfolk fine sandy loam	Good	Georgetown Co., S. C.		Slightly acid	No effect
47	Clarksville silt loam	Good	Robertson Co., Tenn.	Wheat	Acid	No effect
48	Clarksville silt loam	Poor	Robertson Co., Tenn.	Clover	Acid	No effect
49	Jordan loam	Good	Cache Co., Utah	Oats	Alkaline	Beneficial
50	Jordan loam	Poor	Cache Co., Utah	Oats	Alkaline	Beneficial
51	Salt Lake clay	Good	Cache Co., Utah	Wheat	Alkaline	Slightly harmful
52	Carrington silt loam	Good	Dane Co., Wis.	Tobacco	Neutral	Harmful
53	Carrington silt loam	Poor	Dane Co., Wis.	Oats	Acid	Harmful
54	Sioux fine sandy loam	Good	Buffalo Co., Wis.	Corn	Slightly acid	No effect
55	Sioux fine sandy loam	Poor	Buffalo Co., Wis.	Rye	Slightly acid	No effect
56	Miami silt loam	Good	Jefferson Co., Wis.	Corn	Neutral	Harmful
57	Miami silt loam	Poor	Jefferson Co., Wis.	Alfalfa	Neutral	Harmful

and gave poor results. In 1912 the soil was heavily manured and again planted to corn. The yield of stover was very poor and no grain was formed.

The laboratory examination of the two soils showed them to be neutral in reaction. The good soil gave no reactions for aldehyde when extracted for this purpose, but the extractive material was slightly harmful. The poor soil, however, gave considerable amounts of aldehyde material, and this was distinctly harmful to the wheat seedlings, reducing growth 28 per cent.

Soil No. 15, the Salt Lake clay from Cache County, Utah, is from a poor spot in an otherwise good field. The remainder of the field is represented by soil No. 51, Table II, and was collected about 35 feet away from the poor spot. The color of the soil in the poor spot is light gray, while the good soil is gray with a pink tint. This spot is generally bare and seldom produces a crop, while the remainder of the field is very productive, yielding from 20 to 30 bushels of wheat per acre. The drainage in the spot is poorer than the remainder of the field. The subsoil of both good and poor soil is a light calcareous clay. Both soils are alkaline in reaction and both showed the same content of water-soluble salts (.03 per cent.). The good sample contained no aldehydes, and such residue as was obtained proved only slightly harmful to wheat seedlings, whereas the poor sample contained considerable aldehydes, which proved very harmful to wheat seedlings in the cultural tests, reducing growth 30 per cent.

Returning now to a discussion of Table I, as a whole, it has been shown that the aldehyde extract is uniformly harmful to the test plants. This becomes apparent from the next to the last column of the table.

In the third column is given the field record of the soils as to their productivity as designated by the collector. The garden soils, as already mentioned, were all soils with which trouble of one kind or another had been experienced. In general this column shows that the soils containing the aldehyde were also poor soils in garden and field, with some few exceptions. In this column is found one notable exception, in the Aurora silt loam, good (No. 7), from Miller County, Missouri. This soil contained aldehyde, whereas the corresponding poor sample

(No. 31, in Table II) from another farm gave no indication of the presence of aldehyde. This observation was confirmed by procuring a new sample 6 months later. The other exceptions are in the Norfolk very fine sandy loam (No. 8) and in the Dekalb silty clay loam (No. 16), in which aldehyde was found, but it will be noticed that in both these cases the poor soil contained the aldehyde also (Nos. 9 and 17). It would appear, therefore, that both good and poor soil samples contained some aldehyde. It might be further pointed out that in both cases the greater productivity of the sample designated as good is doubtless due to the direct fertilizing value of the applied manure, the less productive samples having no manure applied. That manure is not antagonistic to aldehyde is indicated by its presence in the exceedingly well manured garden soils, in the same table (see notes in last column), as well as by some of the field results already given.

Some of the soils given in Table II and showing no aldehydes have been discussed in connection with the preceding table. The remainder require no further discussion here, inasmuch as no aldehyde was found in either the good or poor sample.

From these two tables it is at once apparent that only a relatively small number of the poor soils showed the presence of aldehyde, which means that the poorness of many of the soils in Table II must be attributed to other causes, since soil infertility may be due to a great many factors other than the presence of toxic compounds, and especially any particular toxic compound.

The material extracted in the aldehyde method was in all cases extremely small, gave no aldehyde reactions, but in some cases it proved, nevertheless, harmful. What the nature of the harmful substance in these cases was it is impossible to state. If aldehyde was present, it was at least so small in amount that it escaped chemical detection, nor does the method wholly exclude the occurrence at this place of traces of other compounds. In the majority of cases the material was not harmful, occasionally even showing a slightly good or stimulating effect.

A total of 74 soils is described in the foregoing tables. Of these, 14 were garden and greenhouse soils which had failed to grow crops, and 60 were field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive.

These soils were all examined for aldehydes. Of the 14 garden soils, 5 contained aldehydes, and of the 60 field soils, 12 contained aldehydes.

(1) *In Soils from Widely Different Sections.*—The soils examined were from various parts of the United States; soils from 20 States make up the list. They vary from very unproductive soils to extremely fertile soils.

Aldehydes were found in soils from 9 States as widely separated as New York and Mississippi or Oklahoma. Its presence is, therefore, not confined to any locality.

(2) *In Soils of Different Texture.*—The soils in which the aldehyde occurred are not soils of any specific type or texture. The above list of soils containing the aldehyde comprises clays, clay loams, silt loams, silty clay loams, loams, stony loams, fine sandy loams, and very fine sandy loams. There is, therefore, no apparent relation with soil type or texture.

(3) *In Unproductive Soils.*—The unproductive soils examined can be divided into two classes: (1) Garden soils, comprising soils which have been highly fertilized and manured, heavily cropped and intensively cultivated, and later failed to produce good crops. This class includes several greenhouse soils. (2) Field soils, growing general farm crops with ordinary farm methods of cultivation.

Fourteen poor garden soils were examined, five of which contained aldehydes. All of these soils were very unproductive and failed entirely or grew very poor garden crops. Nine of the 30 unproductive field soils examined contained aldehydes.

(4) *In Productive Soils.*—Of the 30 productive soils examined, 3 contained aldehydes. These were the Aurora silt loam, from Miller County, Missouri; Norfolk very fine sandy loam, from Pender County, North Carolina; and Dekalb silt loam, from Preston County, West Virginia.

(5) *In Acid, Alkaline, and Neutral Soils.*—It is interesting to note that some of the soils which contained aldehydes were acid, some neutral, and others alkaline. Three of the garden soils (Nos. 1, 2, and 3) were acid, one (No. 4) was alkaline, and one (No. 5) was neutral. Of the field soils which contained the aldehyde, ten were acid, one alkaline, and one neutral.

(6) *In Soils Growing Different Crops.*—Four of the soils

which were found to contain aldehydes were garden soils and had been used for growing garden crops continuously for several years. One was a greenhouse soil and had grown carnations and roses.

Twelve of the soils in which aldehyde was found were used for the growth of general field crops. A rotation of several crops was practised on most of these soils. At the time the samples were collected three were in grass, four were growing corn, three were growing cotton, one was in wheat, and one was fallow. These observations, together with the fact that no aldehydes were found on other soils growing the same crop, would seem to indicate that no close relation exists between the crop being grown and the presence of aldehyde.

Rusting of Iron in Water. W. A. BRADBURY. (*Chem. News*, cviii, 307.)—Many years ago Crace Calvert concluded that the rusting of iron in water was occasioned by dissolved carbonic acid and oxygen, the former being the predisposing cause, since no action occurred in its absence. These conclusions have since been widely supported. Experiments conducted by the author show that rusting takes place very rapidly in tap-water, while in well boiled tap-water no rusting should occur. During rusting atmospheric oxygen is absorbed. The solution of iron by carbonic acid should result in the production of hydrogen, thus $Fe + 2H_2CO_3 = FeH_2(CO_3)_2 + H_2$, but in experiments with tap-water no gas could be collected after over a week. Water saturated with CO_2 did evolve considerable quantities of gas. These experiments confirm the view that rusting is due to the combined action of oxygen and carbonic acid, and show that the oxygen is utilized in two ways: (*a*) in the oxidation of the nascent hydrogen liberated, and (*b*) in the oxidation of the iron bicarbonate to rust. Further tests showed that magnesium chloride solution does not act on iron in the absence of carbonic acid, although it has been stated that such solutions do react with iron, even in the cold, according to the equation—$Fe + MgCl_2 + 2H_2O = Mg(OH)_2 + FeCl_2 + H_2$.

Resistanceless Conductors, Hence Permanent Magnets? ANON. (*Sci. Amer.*, cx, No. 25, 497.)—For many years the laboratory of Prof. Kammerlingh Onnes at Leyden has been the centre from which some of the most important advances in low temperature research have been announced. It will be remembered that the Dutch physicist was the first to liquefy helium, the most refractory of all known gases, and that in the course of the experiments the lowest temperature on record, within a degree or so of absolute zero, was obtained. Lately attention has been centred on the remarkable influence of temperature on the electrical resistance of metals. This resistance becomes practically zero before the absolute zero of temperature is reached. Recent newspaper accounts state in somewhat vague terms that remarkable new developments have followed in the train of this work on the conduction of electricity at low temperatures. The question arises, What happens to an electric current once started in a conductor of zero resistance? Its energy is not dissipated as heat, since the ohmic effect is non-existent. Does the current continue to flow indefinitely? If so, a closed loop carrying a current would function as a permanent electromagnet. It is said that something of this kind has been observed.

Rolling of Zinc. ANON. (*The Metal Ind.*, xii, No. 6, 247.)—Experiments have been made in Belgium to ascertain the effects of foreign metals on the rolling of zinc. Ingots weighing 40 pounds were prepared by casting zinc alloys of various metals, with spelter containing lead 1.05 to 1.25 per cent., cadmium 0.076 to 0.11, and iron 0.03 to 0.039 per cent. Cadmium is harmful above 0.25 per cent., while with 0.5 per cent., rolling is impossible. Arsenic, 0.02 per cent. markedly increases the hardness, and with 0.03 per cent. the metal is too brittle for practical purposes. Antimony is less objectionable than arsenic, as 0.07 per cent. does not increase the hardness; but 0.02 per cent. is enough to produce a striated surface on the rolled sheet, which makes it unsalable. Tin is objectionable when over 0.01, and prohibitive at 0.03 per cent. Copper does not harden until it reaches 0.08, and with 0.19 per cent. the zinc is unworkable. A permissible maximum of iron is 0.12 per cent., but this is easily reduced in refining. Though 1 to 1.25 per cent. of lead does not interfere with the rolling, a slight increase not only seriously affects the malleability, but the excess of lead remains unalloyed and forms patches on the sheet. The presence of two or more impurities together results in a combination of the injurious effects of each.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

COMBUSTION CALORIMETRY AND THE HEATS OF COMBUSTION OF CANE SUGAR, BENZOIC ACID, AND NAPHTHALENE.[1]

Hobert C. Dickinson.

THE uniform standardization of combustion calorimeters of the Berthelot bomb type can best be accomplished by the combustion of substances having a known heat of combustion.

Part II of this paper deals with a series of determinations of the heats of combustion of three of these substances,—sugar, benzoic acid, and naphthalene,—while Part I deals with a study of the general problem of the bomb calorimeter.

A critical study of the stirred water calorimeter as used for bomb combustion shows that the sources of error are mainly of four kinds; viz., (1) temperature measurement, (2) evaporation, (3) lag effect (*i.e.*, failure of some parts of the system to reach a steady condition with sufficient speed), and (4) uncertainties as to the boundaries of the calorimeter (*i.e.*, as to what portions should be included in its heat capacity). It is shown that most of the errors may be avoided by the use of resistance thermometers and by the proper construction of the calorimeter and its jacket.

The cooling corrections for a calorimeter, designed in accordance with the conclusions reached, can be made by a very simple procedure and with an accuracy corresponding to perhaps 1 part in 10,000 of the total amount of heat measured.

A method of electrical calibration was used, which enables the results of combustion observations to be expressed directly in calories almost independently of the electric units, or, if the heat capacity of the electric heating element used in the calibration is known, to be used to check serious errors in either the calorimetric system or the electrical calibrating system.

Observations have been made with two different calorimeters

* Communicated by the Bureau.

[1] Scientific Papers of the Bureau of Standards.

built especially for the purpose and each calibrated by the above method several times independently. Both calibrations and combustions cover a period of more than three years during which time hundreds of observations have been made with different electrical equipment, and samples of material obtained from different sources and purified at different times and in different ways.

Determinations of the heat of combustion of naphthalene gave 9622 ± 2 20° calories per gramme weighed in air, with a maximum deviation from the mean of about 5 in 10,000 for groups of observations upon the same samples and about the same maximum deviation of different groups of observations from the mean of all, regardless of the sample.

Determinations of the heat of combustion of benzoic acid gave 6329 ± 1 20° calories per gramme weighed in air, with a maximum deviation of about 1 in 1000 for the earlier experiments and 5 in 10,000 for the later ones. Observations taken on samples, some by no means pure, from different sources, show a maximum deviation of 15 in 10,000 and a mean deviation of 7 in 10,000.

Determinations of the heat of combustion of sucrose, fewer in number, gave 3949 ± 2 20° calories per gramme weighed in air. The later observations show a maximum deviation of a little less than 1 in 1000 and a mean deviation of about 3 in 10,000, though the earlier ones show a maximum deviation of 15 in 10,000.

It appears that, of the three materials included in this investigation, benzoic acid is the most desirable as a combustion standard, as indicated by the agreement between the results of different observers. Naphthalene has been found very reliable and convenient, although it requires care in handling since a gramme briquet will lose more than 1 milligramme per hour by sublimation. An accuracy of 3 parts in 10,000 is attainable.

Sucrose seems not to be so well adapted for use as a combustion standard as is benzoic acid because of its lower heat of combustion, its frequent failure to ignite, and the lower precision of the results obtained.

Various factors, viz., temperature measurement, stirring, thermal conduction, convection, boundaries of the calorimeter, cooling corrections and lag effects, affecting the accuracy of calo-

rimeters, are discussed and some of the principles involved in the design of an accurate calorimeter are pointed out.

An electrical method used in the calibration of bomb calorimeters is described and discussed.

The results of an extended series of determinations of the heats of combustion of sucrose, benzoic acid, and naphthalene are tabulated and discussed.

The paper also contains a partial bibliography of the subject.

[ABSTRACT]

THE TESTING OF POTENTIOMETERS.*

Frank Wenner and Ernest Weibel.[1]

FOR precise measurements with a potentiometer the errors in the adjustment of the resistance sections or coils in the apparatus must be known. These errors can be determined by measurements of the resistances of the various sections, but, without some systematic method of applying corrections, are not easily allowed for in the use of the potentiometer.

We have found that it is convenient to express the relation between the known electromotive force, the unknown electromotive force, the readings and the corrections by the formula

$$E = f\ [(e_1 + a_1) + (e_2 + a_2) + etc.]\quad (1 + b + c + d) \quad . \quad . \quad . \quad . \quad (1)$$

where

E is the value of the unknown electromotive force,

f is the range readings,

e_1 is the reading of the highest dial,

e_2 is the reading of the next highest dial, etc.,

$c = \frac{S - s}{s}$ where S is the value of the known electromotive force and s is the reading of the known electromotive force dial or dials, and

b, d, a_1 and a_2, etc., are small corrections due to errors in the adjustment of the various resistance sections.

The correction a_1 depends only on the reading e_1, a_2 depends only on e_2, etc., b depends only upon the reading s, and d depends only upon f. A table can therefore be constructed for each dial

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* Presented at the Washington, 1914, meeting of the American Physical Society.

[1] Scientific Papers of the Bureau of Standards.

giving the corrections corresponding to each of its possible readings.

Let R_e be the resistance in the potentiometer between the E-terminals and R_s that between the S-terminals. Then if the total current is independent of the settings of the various switches or plugs,

$$E = S\,R_e/R_s = f\,[(e_1 + a_1) + (e_2 + a_2) + etc.]\,(1 + b + c + d) \ldots . (2)$$

Thus if R_e/R_s is determined for the various readings of f, of e and of s the corrections b, d, a_1, a_2, etc., can be determined.

In the paper various methods which have been used in the Bureau of Standards for measuring, or determining, the relative values of the resistance sections of different types of potentiometers are described. Also a procedure is given by which, for certain types of potentiometers, the corrections b, d, a_1, a_2, etc., may be obtained from the relative values of the resistance sections.

In order to reduce the time required for making the measurements and to obtain the data in such form that the corrections can be more easily calculated, a special piece of apparatus was constructed and has been in use during the past two years. This apparatus, which we shall call a ratio set, has been found to furnish a rapid and direct means for calibrating all types of potentiometers which have so far been submitted to the Bureau of Standards for test. It is equivalent to 211 110 resistance sections of .01 ohm each, connected in series and so arranged that a branch connection (either to battery or galvanometer) can be made between any two adjacent sections; or it is equivalent to a slide wire on which contact can be made at 211 110 points. The apparatus is made of 100 resistance sections, 20 of each of the following denominations; 100 ohm, 10 ohm, .1 ohm, and .01 ohm. Five dial switches serve to shift resistance sections from one side to the other of the branch connection, or to cut out sections on one side and insert corresponding sections into the other side.

In use the ratio set is connected in parallel with the potentiometer to be tested in such a way as to form two arms of a bridge, while the potentiometer forms the other two arms. This arrangement constitutes a Matthiessen and Hockin bridge. The ratio set is adjusted so that a balance of the bridge is obtained for each setting of the dials of the potentiometer for which corrections are

desired. The corresponding readings of the ratio set (when connected for known errors in its resistance sections) give data from which the corrections b, d, a_1, a_2, etc., of equation (1) may be calculated.

Certain adjustments are made (which cannot be explained in a short abstract), such that the corrections are obtained almost directly from readings of the potentiometer and ratio set.

The paper is to be published in the Bulletin of the Bureau of Standards and reprinted as Scientific Paper No. 223. Reprints will be ready after about September 1, 1914, and may be obtained by request from the Director, Bureau of Standards, Washington, D. C.

[ABSTRACT]

AN EXPERIMENTAL STUDY OF THE KOEPSEL PERMEAMETER.*

Charles W. Burrows.

THIS paper gives in detail the results of an experimental study of the possibilities and limitations of the Koepsel permeameter. Data are given to show the influence of the length, cross section, and material of the specimen tested. The different factors which may affect the accuracy of the readings are considered, and the following detailed conclusions drawn:

1. Readings on the two sides of the zero of the instrument may differ considerably, but the mean of the two values thus obtained shows satisfactory consistency on repetition.

2. Shearing curves for different grades of material show that the correction to be applied to the observed magnetizing force is not constant for a given induction, but depends upon the nature of the test specimen. This correction is usually subtractive for points below the knee of the induction curve and additive for points above the knee.

3. An increase in the cross section of the test specimen tends to increase the observed values of the magnetizing force for points below the knee of the induction curve, and to decrease the observed values for points above the knee.

4. The length of the specimen projecting beyond the yokes

* Scientific Papers of the Bureau of Standards.

produces no noticeable effect for points below the knee of the induction curve. For points above the knee the projecting ends increase the observed value of the magnetizing force.

5. If the bushings are not pushed all the way into their proper position, a higher apparent value of the magnetizing force is observed due to the increased length of the portion of the bar under test.

6. Hysteresis loops obtained by the Koepsel permeameter always show a low observed residual induction and a high observed coercive force.

7. A theoretical and experimental study of the distribution of the magnetic fluxes through different parts of the magnetic circuit shows that shearing curves of the form observed are to be expected.

Apparatus of this type, if used without correction, may yield data greatly in error. The results of the present study show that for small and moderate inductions the measured magnetizing force is usually in excess of its true value, sometimes by as much as 100 per cent. At high inductions the measured magnetizing force is usually too low by an error which may be as great as 25 per cent. However, with care, and the use of proper correction curves, the apparatus is capable of yielding quantitative normal induction data in which the error in the magnetizing force is not greater than 5 per cent.

Uncorrected hysteresis data for hard steel show values of the residual induction that are too small by an error which may be as much as 10 per cent., while the coercive forces are too large by an error which may be as much as 40 per cent.

The chief value of such an instrument is for comparative work in which it is desired to determine the degree of uniformity of material or the relative values of similar materials.

SAFETY RULES TO BE OBSERVED IN THE OPERATION AND MAINTENANCE OF ELECTRICAL SUPPLY UTILITIES AND IN HANDLING ELECTRICAL EQUIPMENT.*

THE study of life and property hazards incident to the generation, distribution, and use of electrical energy includes the con-

* Abstract of Circular No. 49.

sideration of both construction methods and operating practice. Analysis of the available data on electrical accidents demonstrates their preventability in very large proportion by use of definite operating precautions. This is especially true with those accidents occurring to workmen engaged in electrical work.

Rules for construction, installation, and maintenance of electrical equipment to safeguard employes and the public are now under preparation by the Bureau of Standards. The rules for safety in the operation and handling of electrical lines and equipment, to be published shortly in their first edition under the above title, proceed from a painstaking study by the engineers of the Bureau of existing rules and practices. These are found to vary widely and to offer a very unsatisfactory basis for the formulation of mandatory codes by any State commission, unless a very extended study is made and the combined experience of many companies and workmen utilized. Many existing sets of rules have been developed from insufficient data and experience, while the vast majority of companies have no rules whatever in effect. This lack of rules in force is partly due to inaction on the part of State authorities and partly to the difficulty and expense each company encounters in preparing its own rules in any adequate form. The assistance of State commissions, operating companies, and electrical workmen has been freely given to the Bureau in this work, and the rules in their present form are offered to the public for criticism, discussion, and, so far as may be found desirable, for general adoption.

The scope of the safety rules includes all operation of, and work on or about, power and signal lines, and the electrical equipment of central stations, sub-stations, mines, and testing departments. The rules are divided into three parts. The first two parts consist of general rules which apply to the employer and to the employe respectively, and the third part comprises, under separate headings, those special rules which apply particularly to employes engaged in special classes of electrical work.

It is intended that employes should thoroughly familiarize themselves with all the general rules as well as those which relate solely to their own particular work.

While all the rules find application in the larger industrial or private plants or to utilities of moderate size, some do not

apply or apply less fully to the smaller organizations. It has seemed unwise to attempt to restrict the rules to those which are entirely applicable to the smallest organizations or to the simplest classes of electrical work, since the number of workers so employed is small compared with the total number to whose work uniform rules should apply.

The individual rules, suggested by conferees and resulting from careful comparisons and selections, have been subjected to careful general scrutiny to determine the necessity for each and its general applicability under varying conditions of operation. The different classes or workers to which the rules apply have been freely consulted. Concreteness, simplicity, and directness have been sought in the formulation of the rules.

After carefully considering each rule and retaining only those essential to the safety of operation, the grouping was made such as to facilitate reference.

The section for employers calls for the provision of employes with rules, diagrams and emergency instructions, their assignment to work according to their demonstrated abilities, and the division of responsibility among them in a definite manner so that danger may not arise through conflict on points of authority. The employer is also required to supply portable safeguards, to enforce general operating precautions, and to supply employes with forms for the adequate reporting of accidents. The final requirement is that the rules for employes be strictly enforced.

Rules for employes in general are subdivided into six groups. The first enumerates those general precautions the necessity for which seems obvious but the non-compliance with which is nevertheless responsible for many injuries. The second presents general operating rules, defining the duties and relations of those employes who direct others, and the operating methods by which safety is required. The third group prescribes the precautions for handling live parts under varying conditions of voltage and location. The fourth and fifth deal with the procedures for assuring the continued safety of work about normally live or moving parts respectively by avoiding all possible sources of misunderstanding in killing parts. The sixth group covers in some detail the procedure for making protective grounds and short circuits.

Special rules for employes comprise nine separate headings, covering the special hazards of work about electrical equipment in stations, at switchboards, about overhead lines, in arc lamp attendance, on underground lines, meter setting, testing, and in tunnel or mine work. Each class of worker is directed to familiarize himself also with the preceding general rules which apply to all classes of electrical employment. By this arrangement, a more adequate and convenient treatment has been realized without unnecessary repetition.

In a carefully prepared appendix the value of organized accident prevention work through safety committees, is emphasized as a means for reënforcing the effectiveness of safety rules. The report on this subject by the Accident Prevention Committee of the National Electric Light Association is briefly abstracted, and citations are made from the reported organizations and methods of several large and small electrical utilities.

The comment of those commissions, companies, and workmen, whose study of the subject has been closest, has been very favorable to the arrangement and substance of the rules given in this edition, and many have expressed a desire to adopt them or to utilize them in preparing similar codes. The requirements of different States and communities should be closely harmonized to secure the best results in reducing the accident toll of electrical service, and the results presented in this code should be advantageous in securing uniformity among the State codes of safety rules.

Great advantage will result to companies and workmen alike by the general adoption by the several States of a single standard set of safety rules, which can be revised in accordance with the progress of the art and the combined experience of all the companies and commissions of the country. Thus will every State and every company secure the advantage of the experience of all.

Where particular rules do not apply, their omission will of course cause no conflict in practice. If it is necessary for any State commission to adopt additional rules, that could be done at any time by special orders. This would be easier and less confusing than to have a different set of rules for each separate State.

Acknowledgment is made of the coöperation by national asso-

ciations, State commissions, company officials, and individuals. The conclusions reached by the Bureau of Standards from the combined experience of many of the most experienced companies and individual engineers and a thorough study of a large amount of literature and statistics are now offered with the hope that they will constitute a substantial contribution to the widely evidenced public need for a standard set of safety rules. It is believed that a material reduction in present life hazards to electrical workers may be realized by the general adoption and use of these rules.

GAS TESTING LABORATORIES.*

THIS circular contains suggestions as to location and equipment of gas-testing laboratories, a description of some of the accepted forms of apparatus, directions for the making of the various tests, and recommendations as to the interpretation of experimental results. It does not discuss the testing work necessary for good works control; it deals rather with methods which are intended for use in city or State official testing, or in works laboratories which are checked by city or State inspectors.

No attempt is made to fix on a single method to be used in every case, for it is not believed that uniformity of method is always necessary in order that the results of tests be considered standard. In each case as much freedom in choice of method is allowed as seems permissible; but the simplest procedure or apparatus with which satisfactory results can be had is given preference. The discussion is so arranged that an inexperienced man may utilize the information, but exactness of description has not been sacrificed in the effort to simplify the directions.

The full discussion of the influence of various conditions upon the results of tests and the theoretical consideration such as would properly accompany a publication of the results of a research are not given in the circular. Such full discussion will be found in the various sources referred to in the text.

Not all the methods which are recommended have been investi

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* "Standard Methods of Gas Testing."—Bureau of Standards Circular No. 48, August 1, 1914.

gated in the laboratory of the Bureau, but every effort has been made to ensure that the use of such methods as have not been used at the Bureau has proven entirely satisfactory in the laboratories of experienced gas testers elsewhere.

The five principal subjects discussed are: measurement of heating value, candlepower determination, determination of impurities (hydrogen sulphide, total sulphur, and ammonia), taking of gas pressure records, and gas meter testing. Full operating directions, including a description of apparatus and precautions which must be observed, are included under each heading.

The Electron as a Vibrating Particle. ANON. (*Sci. Amer.*, cx, No. 20, 409.)—Herr Korn, after observations extending through twelve years, has established a mechanical theory of gravity and of reciprocal molecular effects; the main points of the theory are: Suppose an infinite and incompressible medium with very rapid vibrations, containing slightly compressible particles; such a system is capable of an infinite number of different vibrations. The mathematical investigation of such a system is not difficult, provided we assume that no whirlpools exist. The fundamental vibration will be a pulsation of the particles, and Newton's Law of Gravitation will express the reciprocal effects of these particles, due to this fundamental vibration. If we impose on the vibrating particles the condition of constant velocity of pulsation the electrons may be considered as such pulsating particles. In other words, we must conceive the electrons to oppose a very great resistance to any external action tending to modify their velocity of pulsation; it is also necessary to admit that these extremely rapid vibrations emit very little or no radiation. The duration of these vibrations is extremely great in comparison to the duration of all vibrations hitherto known.

Properties of Plastic Insulating Materials. E. HEMMING. (*Electr. World*, lxiii, 761.)—Insulating materials, which are suitable for molded work, are divided into a number of classes, according to the nature of the materials, such as fibre, rubber, porcelain, etc., of which the insulator is composed. The properties of insulators made of these different materials are stated in a table, which includes information under many various headings, and photographs are given showing a number of articles used for insulating purposes in lamps, plugs, switch-handles, rosettes, etc., which are made from molded materials. Other tables give figures showing the ohmic resistances and the dielectric strengths of molded insulations of different types.

Theory of Ocean and Primitive Continent Formation. E. BELOT. (*Comptes Rendus*, clviii, 647.)—On the earth and on Mars the ocean surface is much greater in the southern hemisphere than in the northern, while upon the moon the volcanic area is much more intense in the south than north, and it is considered that this points to a similar inequality of distribution of the water originally on the moon. This unipolar condensation of water on the earth, moon, and Mars may be easily explained if the relative translation of these three stars in the primitive nebula be assumed, the direction being that of the north part of their axes. This south-north translation had three principal effects: (1) The plastic terrestrial projectile became flattened in front and pointed behind. (2) The rotation, more retarded at the north than at the south pole, gave a twist to every relief in the sense of an easterly rotation of their southern parts. (3) At the exterior of the primitive terrestrial atmosphere, friction upon the nebula determined a general circulation in the sense north to south. This circulation has been demonstrated and investigated by Bossinesq in the case of a drop of water falling through a liquid. About the south pole the atmospheric circulation caused cold vertical currents to descend, and after heating at the earth's surface to ascend hot. Consequently the temperature fell below 364° (the critical temperature of water), producing an abundant condensation of water under the pressures then prevailing. The water currents then set up proceeded to weather out the configuration of the primitive continents. This theory is illustrated by numerous examples of present continental conditions, which in the author's opinion tend to confirm his views.

THE FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

NECROLOGY.

Arthur Otis Granger was born at Providence, February 14th, 1846, and died at his home in Cartersville, Georgia, on July 30th, 1914. He was the son of the Rev. Arthur Granger and Sarah Alcorn Rowan Granger. He was educated in the public schools of Philadelphia, and began his business career in a dry goods store in that city in 1858. In 1876, he organized the firm of A. O. Granger and Company, Engineers and Contractors, Philadelphia, Pa., and four years later he became President of the Granger Water Gas Company, also of Philadelphia. In his later years he was connected with numerous industrial enterprises. He was elected to membership of the Institute in 1877.

Horace Pettit died at his summer residence at Atlantic City, N. J., on August 13th, 1914. He was born in Philadelphia in 1860, and received his early education at the school of Dr. Faries and at the Cheltenham Military Academy. In 1879, he commenced the study of law and was graduated from the Law School of The University of Pennsylvania, four years later. Mr. Pettit was a member of The University Club, The Union League, The Racquet Club, and other organizations. He became a Life Member of The Franklin Institute in 1886, was elected to its Board of Managers in 1894 and served until 1910; he was a member of its Board of Trustees for several years.

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Pennsylvania Topographic and Geologic Survey. Richard H. Hice, State Geologist. Geology of the Broad Top Coal Field, Bedford, Fulton, and Huntingdon Counties, by James H. Gardner. Map, 43 x 45 inches, in colors. Harrisburg, State Printer, 1914.

A Fine Collection of Meteorites. ANON. (*Sci. Amer.*, cx, No. 23, 459.)—The American Museum of Natural History, in New York, has acquired this collection through the generosity of Mr. J. P. Morgan. It comprises the entire stock of meteorites which belonged to the unique establishment in Washington, known as "Howell's Microcosm" at the time of Mr. Howell's death, and includes representatives of 54 falls, weighing in the aggregate about 220 pounds.

Marble Shades and Reflectors. W. VOEGE. (*Elektrotechn. Zeitschr.*, xxxv, 199.)—The use of sheets of marble for diffusing light is proposed. Very thin sheets, 0.1 to 0.5 mm. thick, have been used for this purpose; *e.g.*, cemented to colored glass designs which it is desired to illuminate. For ordinary purposes the cost is excessive. A process has now been discovered by means of which thicker and cheaper plates, 3 to 20 mm. thick, can be used. They are first etched on both sides and then soaked in oil at high temperature and pressure, when they become more transparent than a similar plate of milk glass, and have excellent diffusing properties. It is expected that this material will prove useful for decorative light effects. A series of experiments is described that demonstrates that the marble transmits visible light better than the milk glass, but absorbs the infra-red rays to a greater degree.

CURRENT TOPICS

Heavy Chemicals in the United States. ANON. (*Oil, Paint and Drug Reporter,* May, 1914.)—The imports of bleaching powder in 1913 amounted to 30,800 short tons, compared with 37,120 tons in 1912, 41,450 tons in 1911, 50,500 tons in 1910, 45,700 tons in 1909, and 56,600 tons in 1908. Imports from England have decreased from about 30,000 tons in 1911 to 22,250 tons in 1913, while Germany supplies about 6000 tons annually. The output of American works amounts to about 90,000 tons, of which about 30,000 tons are exported. The output of caustic soda in 1913 reached about 190,000, of which about 20,000 tons were exported. The exports to Canada average about 15,000 to 20,000 drums per year. Arsenic was imported to the amount of 4130 tons in 1910, which dropped to 3340 tons in 1913. Imports from Europe have practically ceased, the only material source of foreign supply being Canada. The output last year in the United States was 2375 tons, and in 1912, 3141 tons.

Recording of Wireless Signals by Means of the Telegraphone. P. DOSNE. (*Comptes Rendus,* clviii, 473.)—The recording of wireless signals on a telegraphone wire or plate, as proposed by Simon and Reich, has been carried out by the author. A sound reinforcer constructed on the principle of that of Berget and Allard has its circuit interposed between the crystal detector employed and the telegraphone recording electromagnet.

The Most Powerful Magnet. ANON. (*Sci. Amer.,* cx, No. 23, 459.)—Probably the strongest electromagnet is produced by the new method successfully applied by Profs. Perot and Deslandres. Their idea is to take one of the strongest electromagnets of laboratory type with pointed pole pieces which already give a high value of the magnetic field, and then to put an extra coil around the air-gap between the poles so as to add considerably to the field. Such coil is made of thin copper strip and is cooled down as low as — 30° C. by a current of oil, so that a remarkably heavy current can be put into the coil without burning it; *e.g.,* it will stand a current density of 1800 ampères per square mm., using a 0.2 mm. strip. Such a coil is put on a Weiss electromagnet which carries the usual coils and gives 41,000 gauss for the magnetic field strength. Putting on the 30,000 ampère-turns of the new coil brought up the field strength to 51,000 gauss, and it was only the lack of current supply that prevented running as high as probably 60,000 gauss, so that a most powerful field can thus be obtained.

Longest Rope Railroad. ANON. (*Amer. Mach.*, xl, No. 26, 1115.)—What is calculated as the longest rope railroad in the world is to be operated in India. It is 75 miles in length, and will connect the rich country in the vale of Kashmir with the plains of the Punjab over the Himalayas. The present longest rope railroad is 22 miles, situated in the Argentine. The sections will be five miles long, and most of the spans will be 2400 feet. The steel towers, some of which will be 100 feet high, will be braced, and double 1½ inch cables, 9 feet apart, will carry the steel cars. The carrying capacity of these cars will be about 400 pounds each.

The Surface Tension of Soap Films. G. F. C. SEARLE. (*Cambridge Phil. Soc. Proc.*, xvii, 285.)—This gives an account of some methods employed at the Cavendish Laboratory for the measurement of the surface tension of soap solution. The methods described are: (1) The *torsion balance method*, in which a rectangular frame of wire is dipped into a soap solution and the pull of the film is measured by the aid of a simple torsion balance. The value of the surface tension was found to be 27.22 dynes/cm. by this method. (2) The *thread method*, in which the surface tension is deduced from the curvature produced in flexible threads dipped in the solution. The surface tension by this apparatus was 27.17 dynes/cm. (3) The *viscosity potentiometer method*, in which the pressure excess due to a spherical soap film is measured; the result of this was 25.19 dynes/cm. (4) The *buoyancy method*, which depends upon the difference of density between cold and hot air at the same pressure. By this method the surface tension was found to be 27.07 dynes/cm.

The Choice of a Trolley Wire. G. H. MCKELWAY. (*Electr. Rly. Journ.*, xliii, 647.)—Points out the matters that should be taken into consideration in determining the most economical size of trolley wire to use in any particular case; the cost of material and labor is based on American rates.

The Greis Smoke Preventing Device. ANON. (*Amer. Soc. Mech. Engin. Journ.*, xxxvi, 649.)—The principle of the apparatus is that of a secondary air supply, regulated and controlled by the opening and closing of the furnace doors. In connection with the use of this device, there is a subsidiary apparatus which produces a mixed steam- and water-fog in the flues, smokestack or chimney. This causes the soot and dust particles to become saturated with moisture, and to fall by their own weight, before they can escape into the atmosphere. The process of washing the hot gases flowing through the smokestack continues as long as one of the smoke-consuming devices on the boilers is in operation. The apparatus does not act until the fire-door is opened; this marks the beginning of the period when the conditions are particularly favorable to an evolution of black smoke.

Aczolling Pole Timber. ANON. (*Elect. Rev.*, lxxiv, 85.)—This describes the preservation of timber by aczol, which is a mixture of metallic ammoniates with an antiseptic acid containing phenols and naphthalenes—the essential preservative elements of creosote. The compound is claimed to have especially great and enduring preservative value. Owing to the solubility of cellulose and vasculose in aczol, the surface layers of the fibres and tissues of the wood treated are coated and cemented together by a combined chemical and physical action which yields secondary and perfectly stable compounds. As sold, aczol contains 15 to 30 per cent. of reinforced phenols and the equivalent of 30 per cent. of copper and zinc salts. This concentrated material is estimated to have 150 times the preservative power actually required to effect sterilization. Hence and because the preservative elements are fixed permanently in the aczol-cellulose compounds, a very dilute solution may be used. Timber to be buried or exposed continuously to weather may be painted with a one in five or six solution of aczol in water. Impregnation is preferable and must be employed for telegraph poles. Injection is by simple immersion for two or three weeks or more rapidly by pressure; cold solution is used. The weight of the timber is hardly increased by treatment; the wood is not rendered objectionable nor dangerous in any way, but is appreciably strengthened, and it can be painted or polished after treatment. By regulating the strength of solution used, timber may be made waterproof or flameproof. None of the ingredients of aczol corrodes iron or other metals, nor do they reduce the insulating value of wood.

Resistometric Studies of Some Iron-Nickel Alloys. A. P. SCHLEICHER and W. GUERTLER. (*Z. Elektrochem.*, xx, 237.)—Wires of three alloys containing respectively nickel 35.25, 30.6, and 25.2 per cent. were heated *in vacuo* in an electric furnace, and their electrical resistance measured at different temperatures. There was a pronounced discontinuity in the temperature-resistivity curve at about 420° C. for the 35.25 per cent. alloy, and at 700° C. for 30.6 per cent. alloy. The 25.2 per cent. alloy in its original condition gave abnormally low values, but the resistance became higher with each successive heating, until the wire became stabilized, and gave a regular curve with a discontinuity at 900° C. The significance of these results is discussed in connection with the constitution of the alloys and their magnetic properties.

Illuminating Engineering Society.—The Eighth Annual Convention will be held in Cleveland, Ohio, September 21st to 25th, inclusive. Papers will be presented by J. R. Cravath, Herbert E. Ives, M. Luckiesh, E. J. Brady, and many others. The subjects are quite varied and cover all problems of illumination, including the physics of the subject. The headquarters of the Society will be at The Hollenden Hotel, where reservations may now be made.

Durability of High-grade Papers. W. HERZBERG. (*Papierfab.*, 478.)—Hjelmsäter exposed a number of papers, both animal-sized and rosin-sized, to full sunlight from June to August, and then tested the deterioration produced. In all the paper, including even the tub-sized hand-made papers, the exposure to light and air produced marked deterioration in the resistance to folding, in many cases this fell to 5 per cent. of the original value. The sizing resistance to ink had disappeared in all cases. The paper belonging to normal class 1, both the animal-sized papers and those doubly sized (both animal and rosin sizes), showed only a slight darkening in color; the rosin-sized samples were much discolored. It was concluded that the deterioration in resistance to folding produced by exposure was in some way connected with the destruction or decomposition of the sizing. From tests in which papers were steeped in solutions of aluminum sulphate, potassium sulphate, and aluminum acetate, and then exposed to light, the author concluded that the deterioration was brought about by the presence of aluminum sulphate; aluminum acetate had no bad effect. Herzberg points out that in the tests recorded, those papers which contained only very small quantities of aluminum salts proved no more resistant than those samples containing comparatively large proportions, so that a directly injurious influence of aluminum sulphate cannot be inferred. The fact that the introduction of a large excess of this salt into the paper was found to be injurious does not prove that papers containing normal quantities are similarly affected.

The Clinkering of Coal. O. W. PALMENBERG. (*Mech. Eng.*, xxxiii, 194.)—One of the most troublesome features in the combustion of coal is due to the production of clinker. This influences the rate of combustion and the cost of maintenance, especially where automatic stokers are used. A coal may clinker so readily under certain conditions that it becomes unfit for use, irrespective of its fuel value. It is therefore of the greatest importance to know whether a coal will clinker under the conditions for which it is required. The determination of the clinkering properties of a coal, that is, whether its ash will fuse at a low temperature, has been carried out in several ways; and many authorities have considered that an analysis of the ash, or determination of the iron in the ash, or of the sulphur in the coal, would furnish the information desired. To show that there is no relation between the clinkering quality of a coal and the sulphur or iron content, the author has made an independent investigation of the problem. Analyses of the ash, together with the fusing temperature determinations on a wide range of coals, show that no conclusions can be drawn from a chemical analysis. It may be noted that some coals have ash of like iron contents and variable fusion temperature; others have ash of like fusion temperature and variable iron content. It would appear, therefore, that there is no relation between the percentage of the

various constituents of the ash and the fusing temperature. Hence a chemical analysis is of no value for arriving at a judgment as to the clinkering quality of a coal. The fusion temperature of the ash ought, therefore, in the future to displace the sulphur determination in coals used for steaming purposes, and this change will readily show the fallacy of buying and selling coal on an analysis basis, where specifications are used containing sulphur tables penalizing beyond a certain guaranteed amount of sulphur. It has been quite a common practice to place 1.5 per cent. of sulphur as a limit, and to penalize the seller as much as 4 cents per ton for every 0.25 per cent. of sulphur above 1.50 per cent. The injustice of this practice is evident, as it often happens that coals with a high sulphur-content are extremely high in heat value, and do not clinker readily. Since the sulphur has no appreciable effect upon the metallic parts of the furnace, it need not be considered in the selection of a coal for steaming purposes. To arrive at the value of a coal for this purpose it is therefore just as essential to make the fusion test of the ash, as it is to make the calorimetric determination. If these two determinations are made, an explanation is readily found as to why two coals of apparently like proximate analyses give entirely different evaporation when fired under like conditions.

Production of Steel Direct from Ore. E. HUMBERT and A. HETHEG. (*Iron and Steel Inst.*, May, 1914.)—Tests were made with Swedish and Brazilian iron ores in a Héroult electric furnace of six tons capacity, using coke as fuel. The conclusions reached are: that the economic manufacture of steel from ore is practicable; that the product, on account of its comparative freedom from hydrogen, nitrogen, and other impurities, is superior, especially in toughness, to steel obtained by present methods; that the electric furnace employed should be of a type permitting violent ebullition of the bath without overflowing; that either charcoal, coke or anthracite may be used as fuel; and that anthracite electrodes will probably be most economical.

Demolition of the First Skyscraper. ANON. (*Sci. Amer.*, CX, No. 18, 359.)—To make way for a larger structure, there has recently been demolished a ten-story tower building at 60 Broadway, New York City. The building was erected in 1889 and has been in service about 25 years. Naturally the condition of its framework was of considerable interest to architects and engineers. The frame consisted of cast-iron columns and wrought-iron floor beams. The floors were of flat arch terra cotta construction. The framework was found in excellent condition, the wrought-iron beams showing a practical absence of rust, and the cast-iron columns, with a three-inch cast-iron shell around them for fire protection, showing only a few localized patches of rust, and heavy rusting only at a few special points.

Observations on the Burning of Porcelain. R. REINDEL. (*Spreschsaal*, xl, vii, 285.)—The behavior of an experimental oven was studied by the help of Seger cones, a pyrometer, a manometer, and the analyses of the oven gases. The readings of the pyrometer showed higher temperatures than those indicated by the cones, the difference amounting sometimes to 100° C. at the commencement of the heat and diminishing at later stages. Temperature curves were not regular in their ascent, but dropped at every addition of fuel. The draught also varied from 25 to 50 mm. according to the condition of the fire. Analyses of the fire gases were conducted at cone *09a*, the point at which they begin to influence the character of porcelain. A content of 3 to 5 per cent. of carbon monoxide is necessary at this temperature, but at cones 8 or 9, one per cent. is sufficient to maintain the reducing character of the oven atmosphere so far as regards porcelain.

Possible Cause of Explosions in Coal Mines. W. A. D. RUDGE. (*Nature*, xcii, 660.)—A cloud of dust suddenly projected against an insulated wire may charge it up to such a potential that sparks several cm. in length are produced; the material of the dust does not much matter, except as to the sign of the charge. Experiments made in Ludlow Pit at Radstock, the observer walking behind a train of wagons with a Wulf electrometer provided with a radium-tipped collector, yielded potentials of 280 volts; but no sparks were observed in the mine. The coal dust in a mine is rarely pure, however, laboratory tests showed that coal dust covered with flue dust from the boilers would not charge a conductor to a sparking potential in this way, whilst pure coal dust and pure flue dust did, the two charges being of opposite signs.

New Reagent for Etching Mild Steel. W. ROSENHAIN and J. L. HAUGHTON. (*Iron and Steel Inst.*, May, 1914.)—The reagent is composed of ferric chloride, 30 gram.; concentrated hydrochloric acid, 100 c.c.; cupric chloride, 1 gram.; stannic chloride, 0.5 gr.; and water, 1 litre; and it is necessary that the surface of the metal to which it is applied be perfectly clean. The reagent deposits a thin film of metallic copper. On hardened steels, especially of low and moderate carbon contents, the results were similar to those obtained with picric acid, etc., but the outlines of the copper films were very sharp, especially on martensite; troostite and sorbite were darkened. On practically pure carbon steels with the usual pearlite-ferrite structure, the effect was the reverse of that obtained by picric acid, etc., the pearlite being unaffected. The reagent proved specially useful for revealing the distribution of phosphorus in mild steels, giving results which compared favorably with those obtained by Stead's method of heat-tinting. In addition to the typical etching effect, discolored patches surrounding small black pits were frequently observed, usually grouped around a slag-enclosure.

Atmospheric Pressure at Great Heights. ANON. (*Sci. Amer.*, cx, No. 18, 359.)—It is usually supposed that at great heights the pressure of the air is almost negligible, but the application of an ingenious method indicated by Ramsay gives interesting results. He asserts that the green line characteristic of the spectrum of krypton remains visible under a pressure of 0.000035 mm. of mercury. Now this green line is found in the spectrum of the aurora borealis, and it seems to be well established that this exists frequently at altitudes between 100 and 200 miles, and even sometimes up to nearly 500 miles. But krypton is one of the heaviest gases in our atmosphere. It would seem, therefore, that the density of the air at these altitudes is by no means negligible, as whatever the cause may be of the presence of krypton there, it could not remain there unless the air possessed an appreciable density.

Core for Babbitt. ANON. (*The Metal Ind.*, xii, No. 6, 252.)—In castings of babbitt metal it is often necessary to core out some of the parts. A very good core is made of salt and glue. Mix just enough glue into the salt to make a stiff paste, which is shaped or molded in a core box and allowed to harden. This kind of a core can be removed from the casting by soaking it in warm water.

Gyroscopic and Gyrostatic Action. ANON. (*Amer. Mach.*, xl, No. 26, 1128.)—The difference between gyroscopic and gyrostatic action is, briefly, this: Action is gyroscopic when precession is quite free, or controllable at will; and gyrostatic when the axis of rotation is fixed relatively to some large structure. Gyrostatic action is usually incidental and undesirable; gyroscopic is the salient feature of the gyroscope in its various adaptations.

Porosity of Iron. W. H. PERKINS. (*Chem. Soc. Journ.*, cv, 102.)—Perkins repeated and extended Friend's experiments on the absorption of caustic alkalies by iron. Experiments carried out in platinum dishes with sodium, potassium, barium, lithium, and ammonium hydroxides show that distinct traces of alkali are retained by iron and by other metals. Their extraction is a slow process of diffusion and is not hastened by shaking.

Water-proofing Concrete. ANON. (*Sci. Amer.*, cx, No. 21, 425.)—The United States Army engineers have long used the following mixture in water-proofing cement: One part cement, two parts sand, three-quarters of one pound of dry powdered alum to each cubic foot of sand. Mix dry and add water in which three-quarters of one pound of soap has been dissolved to each gallon. This is nearly as strong as ordinary cement, and is quite impervious to water, besides preventing efflorescence. For a wash, a mixture of one pound of lye and two pounds of alum in two gallons of water is often used.

The Kieselguhr Industry. P. A. BORCK. (*Metall. and Chem. Engin.*, xii, 109.)—This article treats of the properties of kieselguhr, its occurrence at Lompoc, California, and other places, and its treatment. Natural blocks can be obtained by sawing the material; these blocks are fairly strong, have a high insulating value, stand heat and cold well, except as to a slight shrinkage, and melt at 1610° C. Light-weight kieselguhr bricks are produced by properly burning the material; they insulate well up to red-heat, but shrink at high temperatures, and must be protected against sudden changes of temperature. They are recommended as backing for more refractory bricks.

Repeated Use of Lubricating Oil after Filtration. G. F. FENNO. (*Min. and Eng. World*, xl, 835.)—In an installation fitted with a Richardson central oiling and filtering system, a high grade mineral oil was supplied continuously to the bearings, and, after filtration and removal of water, was used over and over again. After 18 months the oil was found to have increased somewhat in specific gravity and viscosity, owing to admixture with some of the cylinder oil. The fresh oil showed a slighter lower coefficient of friction on low-bearing pressures, while the friction coefficient of the filtered oil was lower on higher-bearing pressures, but the difference was so small as to be negligible under working conditions. The saving in cost of oil with a plant using two Richardson filters, each taking about 75 gallons per hour, is estimated at $2000 per month.

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